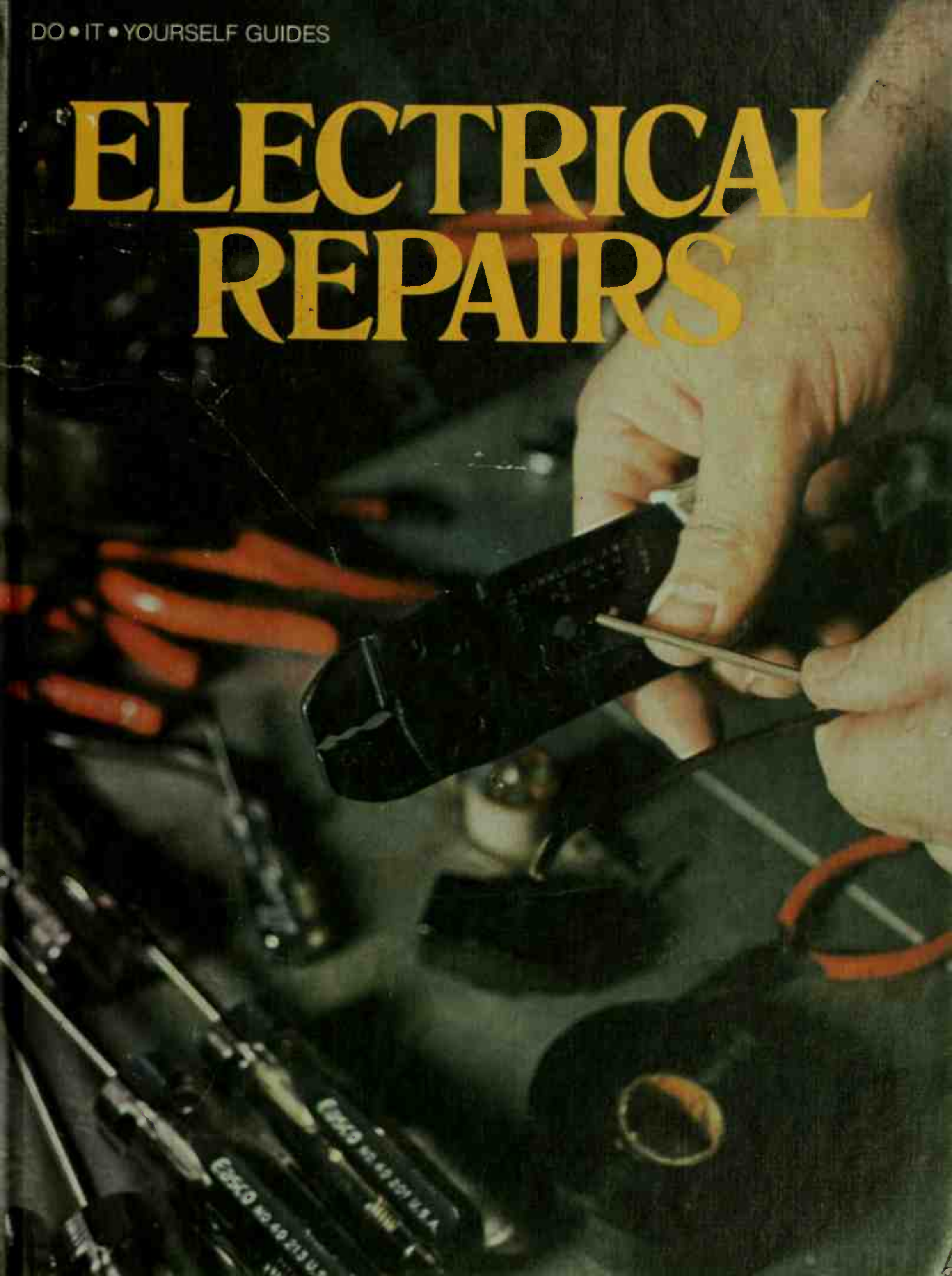
DO • IT • YOURSELF GUIDES

ELECTRICAL REPAIRS



ELECTRICAL REPAIRS

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Contents

1
Fundamentals of Electricity

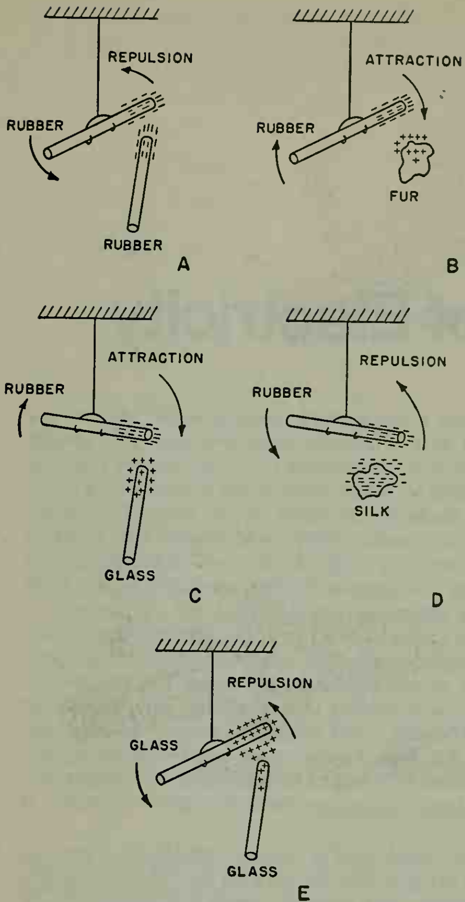
The word *electric* comes from a Greek word meaning *amber.* Amber is a translucent yellowish material that is actually fossilized resin. The ancient Greeks used the words *electric force* in referring to the mysterious forces of attraction and repulsion exhibited by amber when it was rubbed with a cloth. They did not understand the fundamental nature of this force. They could not answer the seemingly simple question, What is electricity? This question is still unanswered. Though electricity might be defined as the force that moves electrons, this would be the same as defining an engine as the force that moves an automobile. The effect has been described, not the force.

In an attempt to explain the nature of this force, English physicist William Gilbert in 1600 divided all substances into two classes: electrics and nonelectrics. He classified an electric as any substance possessing the property of amber, and a nonelectric as any substance not possessing the property of amber. Although such a classification is not acceptable today, the word *electric* from the Greek *elektron* has been handed down and is still commonly used. If a piece of amber is rubbed, it is said to be electrified, or charged with electricity, and the invisible force around an electrified piece of amber is called an electric force.

In 1733 a Frenchman named Charles du Fay observed that when a piece of glass is rubbed with cat's fur, the glass and the cat's fur both become electrified and that the glass will attract some charged objects that are repelled by the cat's fur and vice versa. From this observation, he concluded correctly that there are two exactly opposite kinds of electricity.

Benjamin Franklin introduced the terms positive (+) and negative (−) into the science to distinguish between the two different kinds of electricity. Franklin defined a positively charged body as one that exhibits the same kind of charge as that associated with a piece of glass after it is rubbed with silk. He defined a negatively charged body as one that exhibits the same kind of charge as that associated with a rubber rod after it is rubbed with cat's fur. He defined as electrically neutral all bodies that exhibit no charge.

From time to time various scientists have found that electricity seems to behave in a constant and predictable manner in given situations or when subjected to given conditions. These scientists, such as Faraday, Ohm, Lenz, and



Charles du Fay discovered the attraction and repulsion of charged bodies.

Kirchhoff, to name only a few, observed and described the predictable characteristics of electricity and electric current in the form of certain rules. These rules are often referred to as laws. Thus, though electricity itself has never been clearly defined, its predictable nature and easily used energy has made it one of the most widely used power sources in modern time. By learning the rules, or laws, applying to the behavior of electricity and by understanding the methods of producing, controlling, and using it, we can understand electricity without ever having determined its fundamental identity.

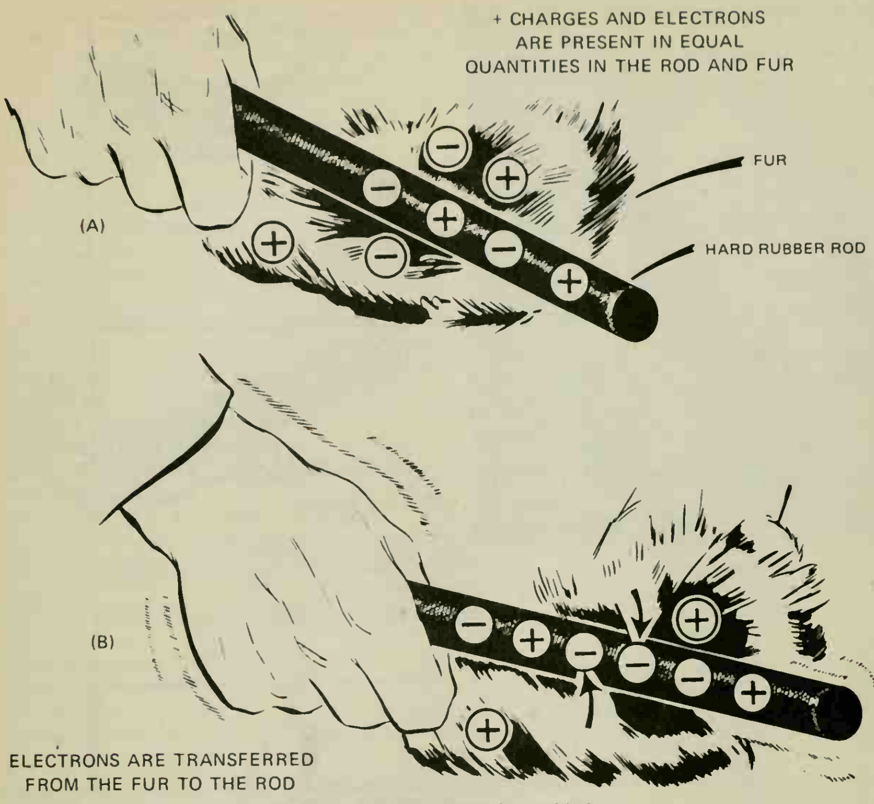
The first type of electric current in general use was direct current from wet cells and batteries. In 1819 Hans Christian Oersted, a Danish physicist, was experimenting with direct current and accidentally discovered that a wire carrying an electric current affected a compass needle and was, therefore, itself a kind of magnet. This was called an electromagnet to distinguish it from a natural or artificial magnet. In either case, the magnetic lines of force, or the magnetic field of a wire or coil carrying a current is the same as that of a natural magnet. Oersted's discovery meant that electricity and magnetism were closely related since one could be used to produce the other. However, it was not until 1831, twelve years later, that Michael Faraday in England and Joseph Henry in America were able to prove the converse—namely, that a magnet could be made to produce an electric current.

AC VS. DC

The flow of electrons through a conductor is called electric current or electron flow. During the early study of electricity, electric current was erroneously assumed to be a movement of electrons from a positive charge to a negative charge. This assumption, termed conventional current flow, is a concept that became entrenched in the minds of many scientists, technicians, and writers. Consequently, conventional current flow is mentioned in many textbooks, and electricians will tell you that the flow is positive to negative. However, since this early concept was stated, it has been determined that the direction of electron movement is from negative to positive.

Electric current is generally classified as direct current (DC) or alternating current (AC). Direct current flows in the same direction, whereas alternating current periodically reverses direction.

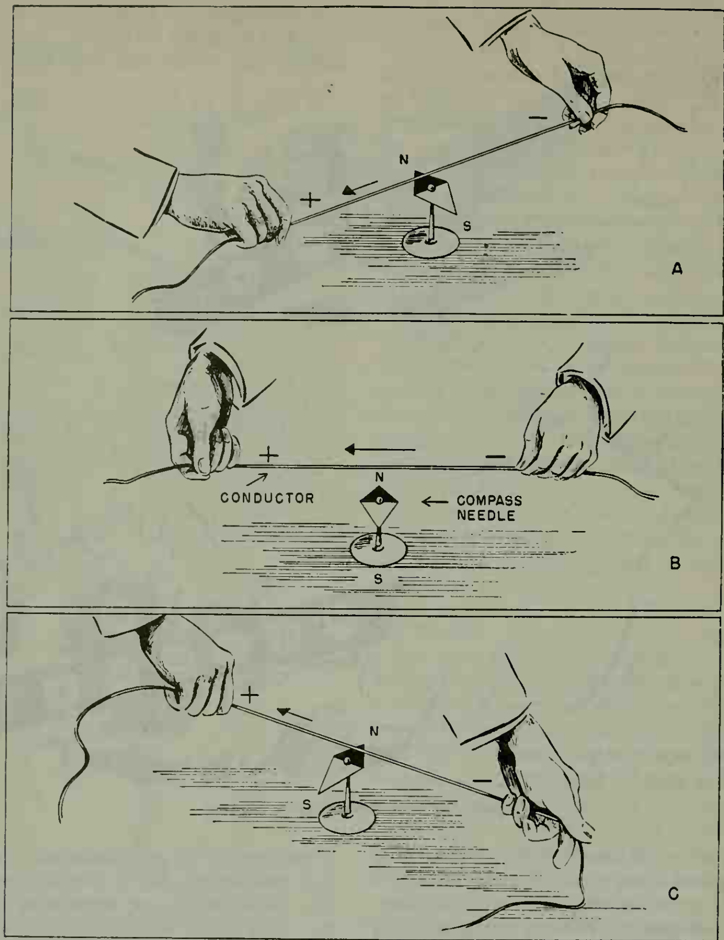
Alternating current is an electric current that moves first in one direction for a fixed period of time and then in the opposite direction for



Producing static electricity by friction

the same period of time. Unlike direct current, which reaches some value, or magnitude, in a short time and then remains at that magnitude as long as the circuit is complete, alternating current is constantly changing in magnitude. From a zero value, alternating current cycles up to a maximum in a positive direction and then falls off to zero value again (the condition of no current flow) before cycling up to a maximum in the opposite or negative direction and then finally returning again to zero.

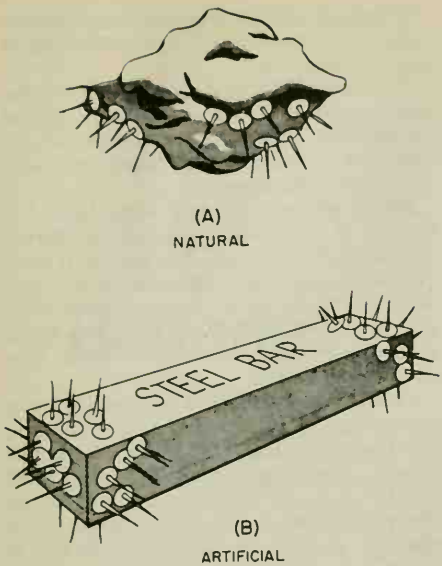
Although direct current was the first type of current to be widely used and the first whose characteristics were understood, it is limited in the number and kind of its applications to power machinery and electronic circuits, and it is used today only in special circumstances. The characteristics of alternating current, on the other hand, were not clearly understood until the end of the last century, and its efficient use as a source of power is a more recent development. In fact, direct current still supplies power to older sections of some American cities because these sections were originally electrified before machinery that used alternating current had become widely available. Direct current must continue to be supplied to these areas until all their electrical apparatus and machines have been replaced or converted to use alternating current.



Oersted's experiment

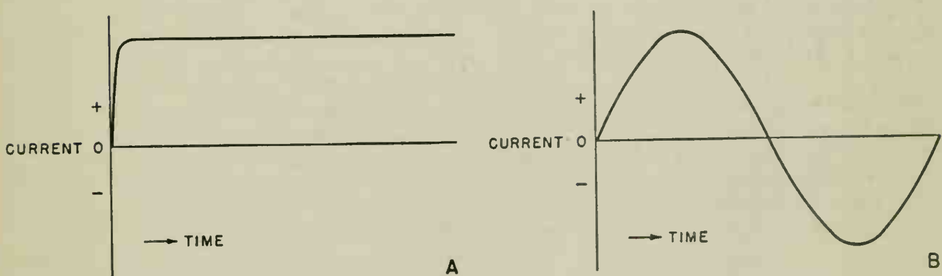
As indicated above, the first electrically powered machinery was designed for use with direct current, which at that time seemed simpler to handle than alternating current. It was soon evident, however, that the use of direct current in most applications had certain disadvantages that were not characteristic of alternating current.

Direct current cannot be transmitted over long distances without a considerable loss of power. Alternating current, on the other hand, can be sent cross-country without appreciable loss of power at high voltage on the now-familiar high-tension wires. Locally, these voltages are transformed to the voltage needed for use in factory or home.



A natural and an artificial magnet

Michael Faraday proved that a magnet could be used to produce an electric current.



Graphs showing the difference between AC and DC. A shows direct current; B shows alternating current.

A second major disadvantage of direct current is that it cannot be radiated from an antenna. The whole art of radio communication as we know it today depends largely on the capability of alternating current to radiate its energy into space from an antenna and to project this energy for long distances over the surface of the earth.

Accordingly, alternating current gradually became recognized as a more suitable and versatile source of power than direct current, particularly since alternating current has the overall advantage of being converted with relative ease to direct current. On the other hand, the conversion from DC to AC, though possible, is often neither convenient nor easy. This

does not mean that DC is outmoded or useless. There are many situations in which direct current is the proper if not the only source of power, particularly in mobile installations where the initial source of power is the DC storage battery, as in cars and airplanes.

AMPERES, VOLTS, WATTS

To determine the amount of current (number of electrons) flowing in a given conductor, it is necessary to adopt a unit of measurement of current flow. The *ampere* is the unit of measurement of the rate at which current flows (the rate of electron flow). The abbreviation for ampere is *amp.* One ampere may be defined as the flow of a specific number of electrons per second past a fixed point in a conductor.

Voltage is a measure of the force that causes free electrons to move in a conductor as an electric current. When a difference in potential exists between two charged bodies connected by a conductor, electrons will flow along the conductor. The force that causes the movement from the negatively charged body to the positively charged body is called electromotive force. A *volt* is the unit of measurement of electromotive force.

A fundamental law of electricity is that the current is directly proportional to the applied voltage; that is, if the voltage is increased, the current is increased. If the voltage is decreased, the current is decreased.

Power, whether electrical or mechanical, is the rate at which work is being done. Work is done whenever a force causes motion. If a mechanical force is used to lift or move a weight, work is done. However, force exerted without causing motion, such as the force of a spring compressed between two fixed objects, does not constitute work.

Voltage is electrical force, and voltage forces current to flow in a closed circuit. However, when voltage exists between two points but current cannot flow, no work is done. This situation is similar to the spring under tension that produces no motion. When voltage causes electrons to move, work is done. The rate at which this work is done is called the electric power rate, and its measure is the *watt.*

2 Batteries

Although our knowledge of electricity and magnetism dates back thousands of years, little progress in the science of electricity was made until late in the eighteenth century when the electric cell, or battery, was discovered by Luigi Galvani, an Italian physicist. The discovery occurred while Galvani was preparing an experiment for a class in anatomy. For the experiment, Galvani had removed frog legs from a salt solution and had suspended them by means of a copper wire. He then noticed that each time an iron scalpel was brought in contact with a frog leg, a reaction occurred; that is, the leg jerked. Galvani concluded incorrectly that electricity was produced by the muscles of the frog. Just three years later, Allessandro Volta, another Italian scientist, found that the muscles did not produce the electricity but rather the electricity was the result of chemical action between the copper wire, iron scalpel, and salt solution. Pursuing these findings still further, Volta built the first electric battery, which he called a voltaic pile.

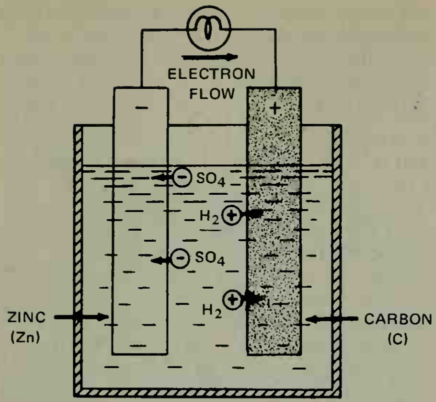
Today batteries are widely used as sources of direct current in automobiles, boats, aircraft, ships, portable electric/electronic equipment, and lighting equipment. In some instances, they are used as the only source of power; in others, they are used as a secondary or standby power source. A battery consists of a number of cells assembled in a common container and connected to function as a source of electric power.

THE CELL

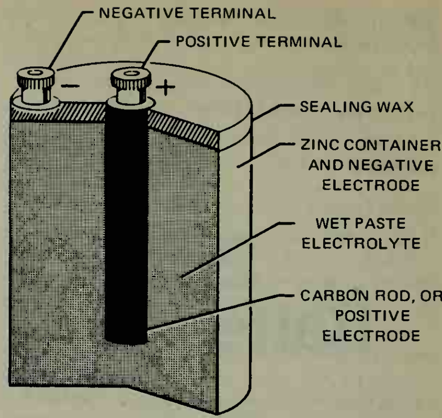
The cell, which is the fundamental unit of the battery, is a device that transforms chemical energy into electrical energy. The simplest cell is known as either a galvanic or voltaic cell. It consists of two electrodes (a piece of carbon and a piece of zinc) suspended in a jar that contains an electrolytic solution (a solution that conducts electricity).

The electrodes are the conductors through which the current leaves or returns to the solution. In the simple cell, they are carbon and zinc strips, while in the dry cell, they are the carbon rod in the center and the zinc container in which the cell is assembled.

The electrolytic solution reacts chemically with the electrodes, which are placed in it. The electrolyte may be a salt, an acid, or an alkali. The simple



A simple voltaic cell



The basic form of a dry cell, shown in a cross-sectional view

galvanic cell and the automobile storage battery contain electrolytes in liquid solution. In the dry cell, the solution takes the form of a damp chemical paste.

Primary Cell

A primary cell is one in which the chemical action eats away one of the electrodes, usually the negative. When this happens, the electrode must be replaced or the cell must be discarded. In the galvanic cell, the zinc electrode and the liquid solution are usually replaced when this happens. In the case of the dry cell, it is usually cheaper to buy a new cell than to replenish it. Some primary cells have been developed to the state where they can be recharged.

Secondary Cell

Secondary cells, or storage batteries, as they are usually called, are well-known to everyone because they are used to provide electricity for automobile lighting, ignition, and starting systems. Secondary cells supply the electric power for telephone central offices, emergency operation of radio equipment at sea, and for a wide variety of mobile equipment designed for military and civilian use. Portable electric light plants make use of secondary cells for automatic starting.

The term *storage battery* is an unfortunate choice, since the battery does not store electricity. Chemical reactions take place when a direct current of proper polarity is passed through the battery. This process is known as charging. The substances formed react chemically to produce electricity when the battery is in use, and this process is referred to as discharging. Therefore, electrical energy is transformed into chemical energy during charging. When the battery is connected to a load, the chemical energy is reconverted to useful electrical energy. Therefore, it can be said that chemical energy can be stored, but electrical energy cannot be stored.

The operation of the secondary cell, like that of the primary cell, is based on chemistry. However, there is one important difference: the secondary cell can be recharged, restoring it approximately to its original chemical condition and thus extending its useful life. This is not true in the case of primary cells. The negative electrode of the primary cell is consumed during use. Therefore, the dry cell destroys itself and must be replaced with a new cell, since it is not practical to replace its electrode and electrolytic solution. One class of primary cells, the wet cell, can be restored to usefulness by replacing the negative electrode

and the electrolytic solution. However, this replacement of the elements of the cell should not be confused with the recharging process.

BATTERY CHEMISTRY

If a conductor is connected externally to the electrodes of a cell, electrons will flow across the electrodes from the zinc (negative) through the external conductor to the carbon (positive) under the influence of a difference in potential and will return to the zinc through the solution. After a short period of time, the zinc will begin to waste away because of the "burning" action of the acid. If zinc is surrounded by oxygen, it will burn (become oxidized). In this respect, the cell is like a chemical furnace in which energy released by the zinc is transformed into electrical energy rather than heat energy.

The voltage across the electrodes depends on the materials from which the electrodes are made and on the composition of the solution. The difference in potential between carbon and zinc electrodes in a dilute solution of sulfuric acid and water is about 1.5 volts.

The current that a primary cell can deliver depends on the resistance of the entire circuit, including that of the cell itself. The internal resistance of the primary cell depends on the size of the electrodes, the distance between them in the solution, and the resistance of the solution. The larger the electrodes and the closer together they are in solution (without touching), the lower the internal resistance of the primary cell and the more current it is capable of carrying to a load.

When current flows through a cell, the zinc gradually dissolves in the solution and the acid is neutralized. A chemical equation is sometimes used to show the reaction that takes place. The symbols in the equation represent the different materials that are used. The symbol for carbon is C and for zinc, Zn. The equation is quantitative and equates the number of parts of the materials used before and after the zinc is oxidized. As stated previously, all matter is composed of atoms and molecules. The atom is the smallest part of an element, and the molecule is the smallest part of a compound.

A compound is a chemical combination of two or more elements in which the physical properties of the compound differ from those of the elements comprising it. For instance, a molecule of water (H_2O) is composed of two atoms of hydrogen (H) and one atom of oxygen (O). Ordinarily hydrogen and oxygen are gases, but through condensation, they combine chemically to form water, which normally is a liquid. However, sulfuric acid (H_2SO_4) and water (H_2O) form a mixture (not a compound) because no chemical reaction occurs when they are mixed together. The identity of both substances is preserved.

When a current flows through a primary cell that contains carbon and zinc electrodes and a dilute solution of sulfuric acid and water, the chemical reaction that occurs can be expressed as

$$Zn + H_2SO_4 + H_2O \xrightarrow[\text{discharge}]{} ZnSO_4 + H_2O + H_2 \uparrow$$

The expression indicates that as current flows, an atom of zinc reacts with a molecule of sulfuric acid to form a molecule of zinc sulfate ($ZnSO_4$) and a molecule of hydrogen (H_2). The zinc sulfate dissolves in the solution and the hydrogen appears as gas bubbles around the carbon electrode. (A gas is designated by an arrow pointing upward in an equation.) As current continues to flow, the zinc is gradually consumed and the solution changes to zinc sulfate and water. The carbon electrode does not enter into the chemical changes taking place but simply provides a return path for the current.

In the process of oxidizing the zinc, the solution breaks up into positive and negative ions that move in opposite directions through the solution. The positive ions are hydrogen ions that appear around the carbon electrode (positive terminal). They are attracted to it by the free electrons from the zinc, which are returning to the cell by way of the external load and the positive carbon terminal. The negative ions are SO_4 ions that appear around the zinc electrode. Positive zinc ions enter the solution around the zinc electrode and combine with the negative SO_4 ions to form zinc sulfate ($ZnSO_4$), a substance that dissolves in water.

While the positive and negative ions are moving in opposite directions in the solution, electrons are moving through the external circuit from the negative zinc terminal, through the circuit load, and back to the positive carbon terminal. When the zinc is used up, the voltage of the cell is reduced to zero.

Polarization

The chemical action that occurs in the cell while the current is flowing causes hydrogen bubbles to form on the surface of the positive carbon electrode in great numbers until the entire surface is surrounded. This action is called polarization. Some of these bubbles rise to the surface of the solution and escape into the air. However, many of the bubbles remain until there is no room for any more to be formed.

The hydrogen tends to set up an electromotive force in the opposite direction to that in the cell, thus increasing the effective internal resistance, reducing the output current, and lowering the terminal voltage. A cell that is heavily polarized has no useful output.

There are several ways to prevent polarization or to overcome it. The very simplest method might be to remove the carbon electrode and wipe off the hydrogen bubbles. When the electrode is replaced in the electrolytic solution, the electromotive force (emf) and current are again normal. This method is not practical because polarization occurs rapidly and continuously in the simple voltaic cell. A commercial form of voltaic cell, known as the dry cell, employs a substance rich in oxygen as a part of the positive carbon electrode, which will combine chemically with the hydrogen to form water, H_2O. One of the best depolarizing agents used is manganese dioxide (MnO_2), which supplies enough free oxygen to combine with all of the hydrogen so that the cell is practically free from polarization.

The chemical action that occurs may be expressed as

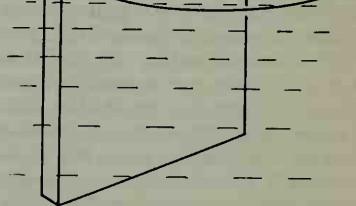
$$2MnO_2 + H_2 \rightarrow Mn_2O_3 + H_2O$$

The manganese dioxide combines with the hydrogen to form water and a lower oxide of manganese. Thus the counter emf of polarization does not exist in the cell, and the terminal voltage and output current are maintained.

Local Action

When the external circuit is opened, the current ceases to flow, and theoretically all chemical action within the cell stops. However, commercial zinc contains many impurities, such as iron, carbon, lead, and arsenic. These impurities form many small cells within the zinc electrode in which current flows between the zinc and its impurities. Thus the zinc is oxidized even though the cell itself is an open circuit. This wasting away of the zinc on open circuit is called local action. For example, a small local cell exists on a zinc plate containing impurities of iron. Electrons flow between the zinc and iron, and the solution around the impurity becomes ionized. The negative SO_4 ions combine with the positive Zn ions to form $ZnSO_4$. Thus, the acid is depleted in solution, and the zinc is consumed.

Local action may be prevented by using pure zinc (which is not practical), by coating the zinc with mercury, or by adding a small percentage of mercury to the zinc during the manufacturing process. The treatment of the zinc with mercury is called amalgamating (mixing) the zinc. Since mercury is 13.6 times heavier than an equal volume of water, small particles of impurities having a lower relative



Local action on a zinc electrode

weight than that of mercury will rise (float) to the surface of the mercury. The removal of these impurities from the zinc prevents local action. The mercury is not readily acted upon by the acid, and even when the cell is delivering current to a load, the mercury continues to act on the impurities in the zinc, causing them to leave the surface of the zinc electrode and float to the surface of the mercury. This process greatly increases the life of the primary cell.

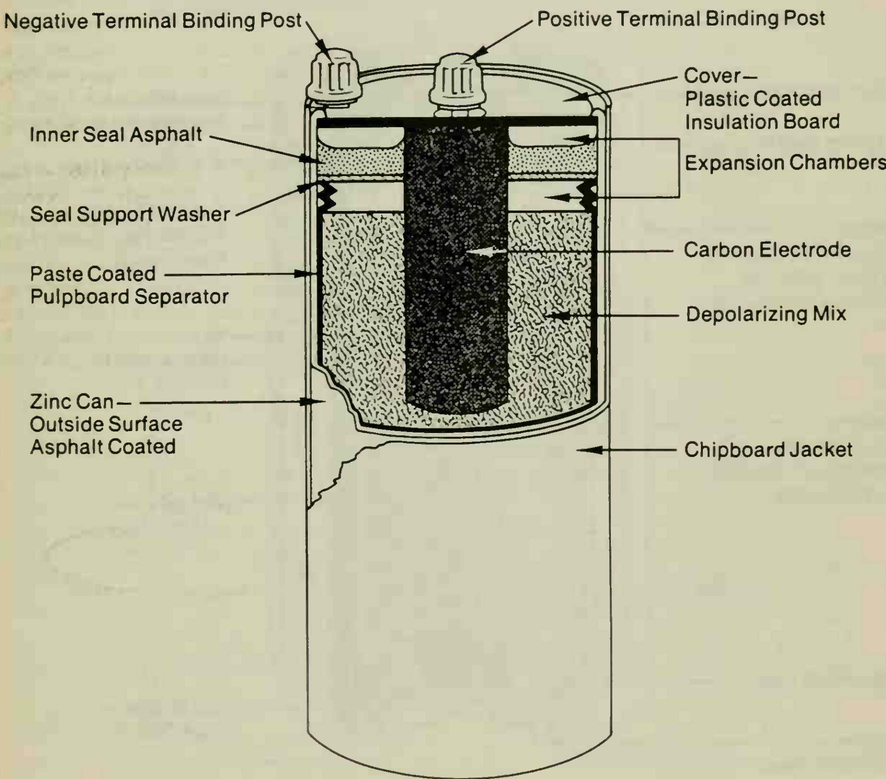
TYPES OF BATTERIES

The development of new and different types of batteries in the past decade has been so rapid that it is virtually impossible to have a complete knowledge of all of the various types currently being developed or now in use. A few recent developments are the silver-zinc, nickel-zinc, nickel-cadmium, silver-cadmium, magnesium-magnesium perchlorate, mercury, thermal, and water-activated batteries.

The lead-acid battery has been in service for a relatively long time; however, improvements are still being incorporated into the battery to improve its efficiency and life span.

DRY (PRIMARY) CELL

The dry cell is so called because its electrolytic solution is not in a liquid state. Actually,



Cross-sectional view of a general-purpose dry cell

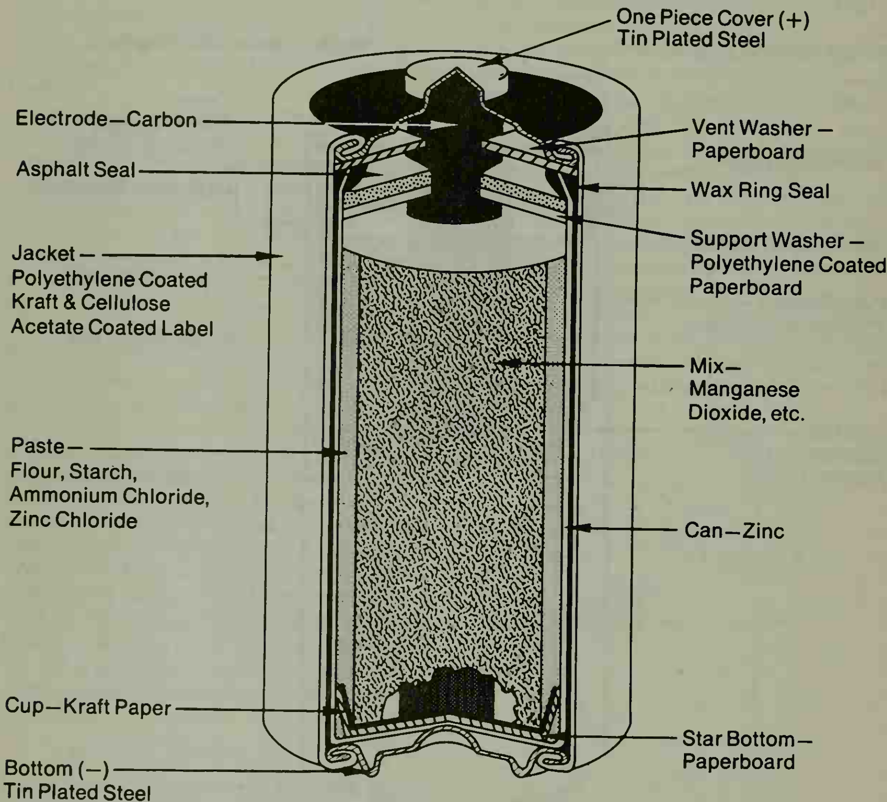
the solution is a paste. If it should become dry, it would no longer be able to transform chemical energy to electrical energy. The name *dry cell*, therefore, is not strictly correct.

Construction of the Dry Cell

In the construction of a common dry cell, the internal parts of the cell are placed in a cylindrical zinc container. This zinc container serves as the negative electrode of the cell. The container is lined with a nonconducting material, such as blotting paper, to insulate the zinc from the paste. A carbon electrode is located in the center, and it serves as the positive terminal of the cell.

The paste is a mixture of several substances. Its composition may vary, depending on the manufacturer. Generally, however, the paste will contain some combination of the following substances: ammonium chloride (sal ammoniac), powdered coke, ground carbon, manganese dioxide, zinc chloride, graphite, and water.

This paste, which is packed in the space between the carbon and the blotting paper, also serves to hold the carbon electrode rigid in the



A cross section of a standard round cell, commonly called a flashlight battery

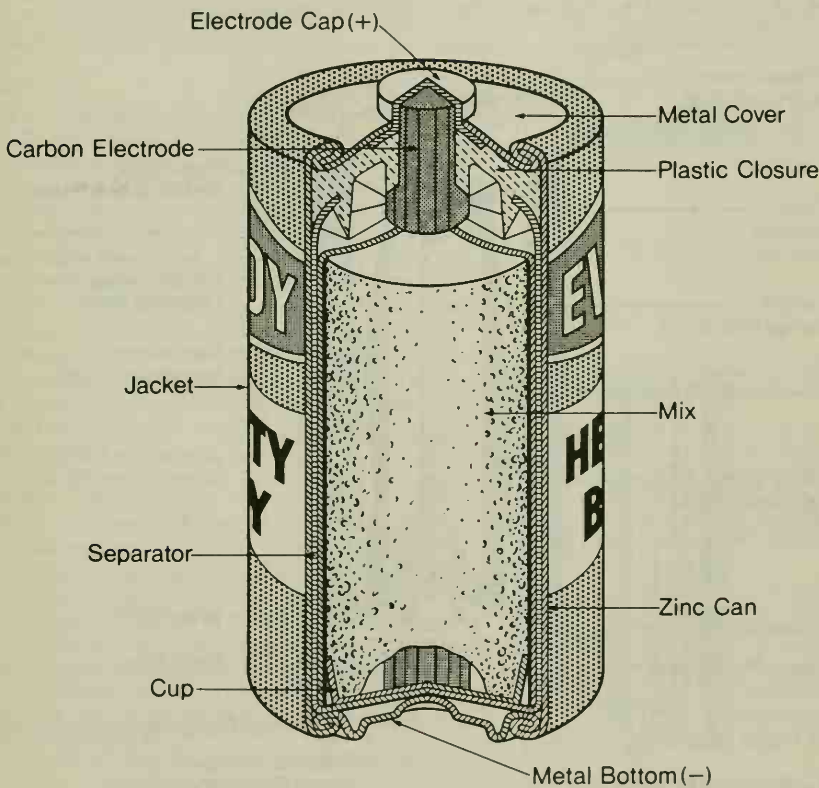
center of the cell. When the paste is packed in the cell, a small expansion space is left at the top. The cell is then sealed with asphalt-saturated cardboard.

Binding posts are attached to the electrodes so that the wires may be conveniently connected to the cell.

Since the zinc container is one of the electrodes, it must be protected with some insulating material. Therefore, it is common practice for the manufacturer to enclose the cells in plastic-coated cardboard tubes before jacketing them in tin-plated steel.

Chemical Action of the Dry Cell

The dry cell is fundamentally the same as the simple voltaic cell (wet cell) in its internal chemical action. The action of the water and the ammonium chloride in the paste, together with the zinc and carbon electrodes, produces the voltage of the cell. The manganese dioxide is added to reduce polarization when line current flows, and zinc chloride reduces local action when the cell is idle. The blotting paper (paste-coated pulpboard separator) serves two purposes: one is to keep the paste from making actual contact with the zinc container, and

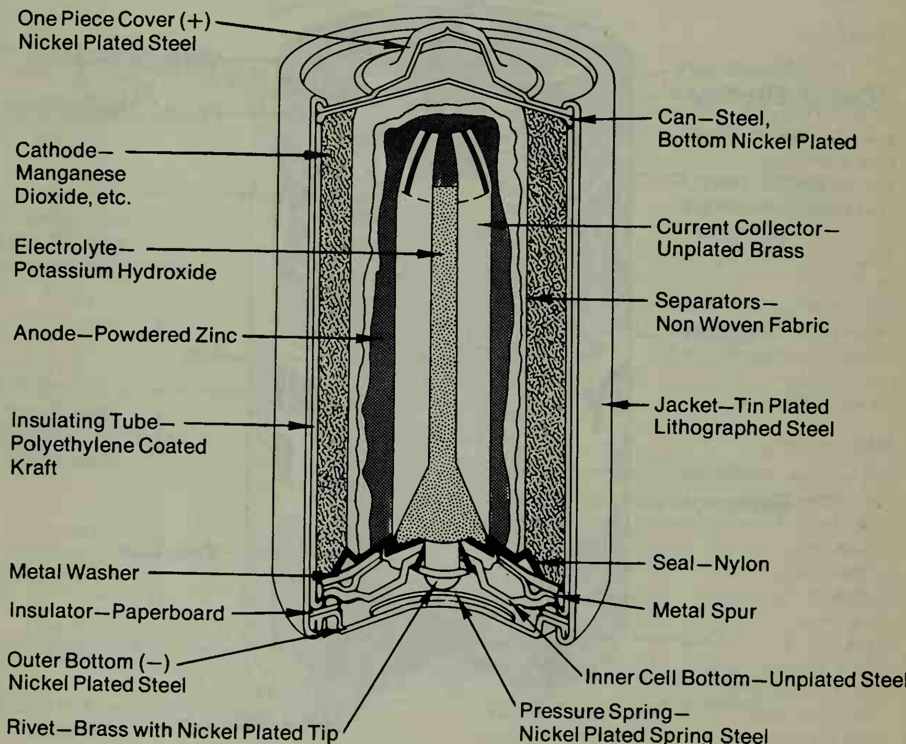


The assembly of a heavy-duty dry cell

the other is to permit the electrolytic solution to filter through to the zinc slowly. The cell is sealed at the top to keep air from entering and drying the solution. Care should be taken to prevent breaking this seal.

Rating of the Standard Cell

One of the popular sizes in general use is the standard, or No. 6, dry cell. It is approximately $2^1/_2$ inches in diameter and 6 inches in length. The voltage is about $1^1/_2$ volts when new, but it decreases as the cell ages. When the open-circuit voltage falls below 0.75 to 1.2 volts (depending on the circuit requirements), the cell is usually discarded. The amount of current that the cell can deliver while still giving satisfactory service depends on the length of time that the current flows. For instance, if a No. 6 cell is to be used in a portable radio, it is likely to supply current constantly for several hours. Under these conditions, the current should not exceed $^1/_8$ ampere, the rated constant-current capacity of a No. 6 cell. If the same cell is required to supply current only occasionally and for only short periods of time, it could supply currents of several amperes without undue injury to the cell. As the duration of each discharge decreases and the interval of time between discharges increases, the allowable amount of current available for each discharge increases—up to the short-circuit amount.



A cutaway view of a primary alkaline cell

The short-circuit current test is another means of evaluating the condition of a dry cell. A new cell, when short-circuited through an ammeter, should supply not less than 25 amperes. A cell that has been in service should supply at least 10 amperes if it is to remain in service.

Rating of the Unit Size Cell

A popular size of dry cell, the size D, is $1^3/_8$ inches in diameter and $2^3/_4$ inches long. It is also known as the unit cell. The size D cell voltage is 1.5 volts when new. A discharged cell may expand, allowing the electrolytic solution to leak and cause corrosion. Some manufacturers place a steel jacket around the zinc container to prevent this action.

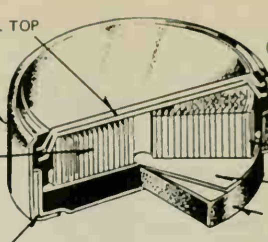
Shelf Life

A cell that is not being used (sitting on the shelf) will gradually deteriorate because of slow internal chemical reactions (local action) and changes in moisture content. However, this deterioration is usually very slow if cells are properly stored. High-grade cells of the larger sizes should have a shelf life of a year or more. Smaller cells have a proportionately shorter shelf life, ranging down to a few months for the very small sizes. If unused cells are stored in a cool place, their shelf life will be greatly increased; therefore, to minimize deterioration, they should be stored in refrigerated spaces (10°F. to 35°F.) that are not dehumidified.

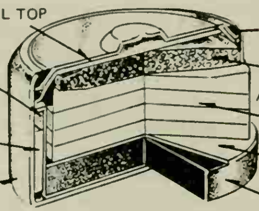
Mercury Cells

With the advent of the space program and the development of small transceivers and miniaturized equipment, a miniature power source was needed. Such equipment requires a small battery capable of delivering maximum electrical capacity per unit volume while operating in varying temperatures and at a constant discharge voltage. The mercury battery, which is one of the smallest batteries, meets these requirements.

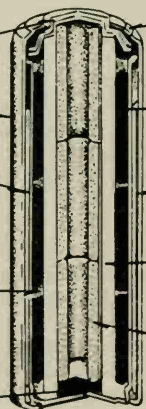
Mercury batteries are now manufactured in three basic structures. The wound-anode type has an anode (negative terminal) composed of a corrugated zinc strip with a paper absorbent



WOUND ANODE FLAT
(A)



FLAT PELLET STRUCTURE
(B)



CYLINDRICAL STRUCTURE
(C)

Three types of mercury cells

wound in an offset manner so that it protrudes at one end. The zinc is amalgamated (mixed) with mercury (10 percent), and the paper is impregnated with the electrolyte, which causes it to swell and produce a positive contact pressure.

In pressed-powder mercury cells, the zinc powder is amalgamated before it is pressed into shape. Its porosity allows electrolyte impregnation with oxidation in depth when current is discharged.

A double can structure is used in the larger cells. The space between the inner and outer containers provides passage for any gas generated by an improper chemical balance or by impurities present in the cell. The cell is constructed so that if excessive internal gas pressure builds up, the upper part of the grommet is compressed enough to allow the gas to escape into the space between the two cans. A paper tube surrounds the inner can so that any liquid carried by discharging gas will be absorbed, maintaining a leak-resistant structure. Release of the excessive gas pressure automatically reseals the cell.

The chemical reaction by which the mercury cell produces electricity is given by the following chemical formula (Hg is the symbol for mercury):

$$Zn + H_2O + HgO \rightarrow ZnO + H_2O + Hg$$

This reaction, the same as in other type cells, is an oxidation process. The alkaline electrolytic solution is in contact with the zinc electrode. The zinc oxidizes (Zn changes to ZnO), thus taking atoms of oxygen from water molecules in the electrolytic solution. This leaves positive hydrogen ions, which move toward the mercuric oxide pellet, causing polarization. These hydrogen ions take oxygen from the mercuric oxide (thus changing HgO to Hg). Where one molecule of water is lost at the negative electrode, one molecule is produced at the positive electrode so that the net amount of water remains constant. By absorbing oxygen, the zinc electrode accumulates excess electrons, making it negative. By giving up oxygen, the mercuric oxide electrode loses electrons, making it positive. In the discharged state, the negative electrode is zinc oxide, and the positive electrode is ordinary mercury.

Mercury batteries have been known to explode with considerable force when shorted. Caution should be exercised to ensure that the battery is not accidentally shorted.

Reserve Cell

A reserve cell is one in which the elements are kept dry until the time of use; the electrolyte is then admitted and the cell starts producing current. In theory, it should be possible to store a reserve cell for an indefinite period before it is activated. In practice, it should be replaced if not used after ten years.

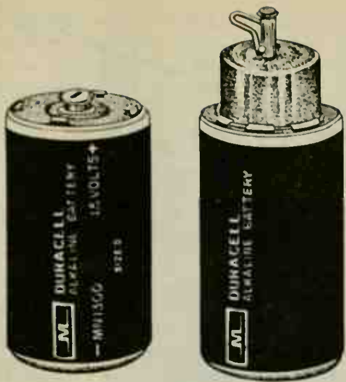
One new reserve cell is the alkaline manganese cell of the standard D size (flashlight battery). This reserve cell exhibits a high efficiency over a wide temperature range and is capable of momentary high current pulses in the range of 12 to 15 amperes.

The reserve cell is manufactured in a dry state. The electrolytic solution is contained in a plastic vial in the cell. When stored in this manner, the cell has a shelf life of over ten years. To activate the cell, the activating mechanism is rotated 35° in either direction. This releases a spring-loaded plunger, which breaks the plastic vial of electrolytic solution. Continued rotation permits the activating mechanism to be removed and discarded, resulting in a D size cell. A safety device is incorporated to prevent accidental activation during handling and transit.

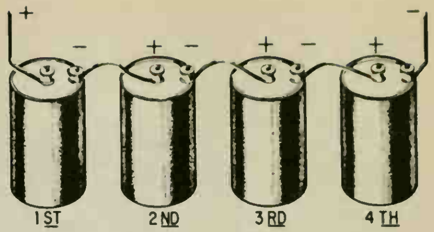
Activation time is approximately two seconds when the cell is not under load. Under a 4-ohm load, the activation time (to reach a 1.35-volt level) is less than five seconds at 70°F. and less than thirty seconds at 30°F.

The cell has been designed so that it is not position-sensitive during either the activation or the discharge period, and after activation it can be handled and used as a standard D cell. After activation, shelf life of the reserve cell is approximately two years less than that of the standard alkaline manganese cell.

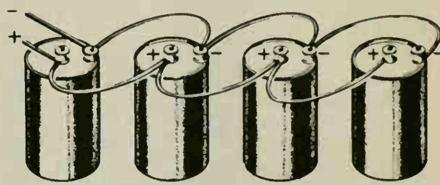
Reserve cells are used for emergency lighting and communications equipment and in any other application where long storage life is of prime importance.



A reserve cell



Cells connected in series



Cells connected in parallel

Combining Cells

In many cases, a battery-powered device may require more electrical energy than one cell can provide. The device may require either a higher voltage or more current, and in some cases, both. Under such conditions it is necessary to combine, or interconnect, a sufficient number of cells to meet the higher requirements. Cells connected in series provide a higher voltage, while cells connected in parallel provide a higher current capacity. To provide adequate power when both voltage and current requirements are greater than the capacity of one cell, a combination series-parallel network of cells must be interconnected.

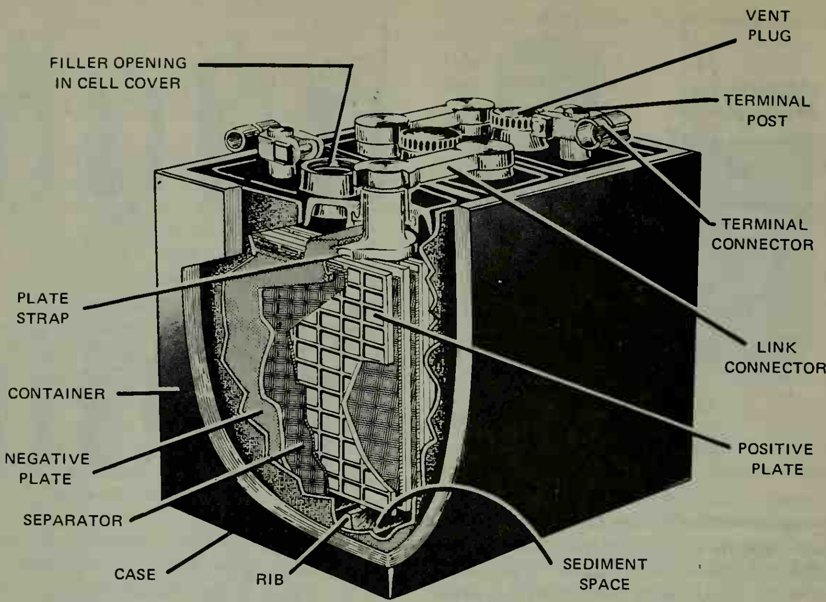
SECONDARY (WET) CELLS

Secondary cells function on the same basic chemical principles as do primary cells. They differ mainly in that they can be recharged, whereas the primary cell is not normally recharged. (As mentioned earlier, some primary cells have been developed to the state where they can be recharged.) Some materials used in a primary cell are consumed in the process of changing chemical energy to electrical energy. In the secondary cell, the materials are merely transferred from one electrode to the other as the cell discharges. Discharged secondary cells may be restored (charged) to their original state by forcing an electric current from some other source through the cell in the direction opposite to that of discharge.

The storage battery consists of a number of secondary cells connected in series. Properly speaking, this battery does not store electrical energy but is a source of chemical energy, which produces electrical energy. There are various types of storage cells—the lead-acid type, which has an emf of 2.2 volts per cell; the nickel-iron alkali type; the nickel-cadmium alkali type, with an emf of 1.2 volts per cell; and the silver-zinc type, which has an emf of 1.5 volts per cell. Of these types, the lead-acid type is the most widely used, and is described here.

Lead-Acid Battery

The lead-acid battery is an electrochemical device for storing chemical energy until it is released as electrical energy. Active materials in the battery react chemically to produce a flow of direct current whenever current-consuming devices are connected to the battery's terminal posts. This current is produced by chemical reaction between the active material of the plates (electrodes) and the electrolyte (sulfuric acid). The lead-acid battery is used extensively throughout the world.



Lead-acid battery construction

Battery Construction

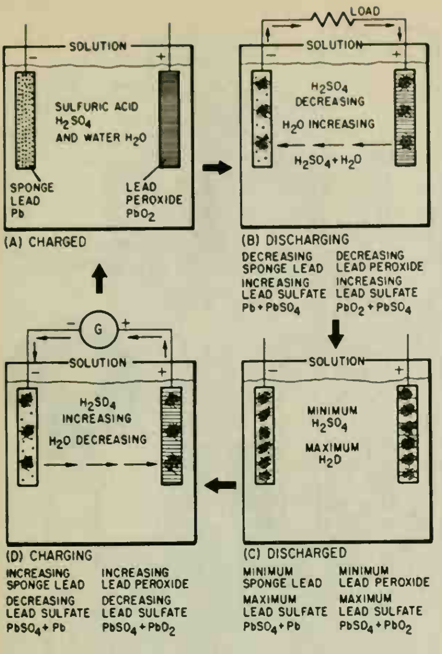
A lead-acid battery consists of a number of cells connected together, the number needed depending on the voltage desired. Each cell produces approximately two volts.

A cell consists of a hard rubber, plastic, or bituminous material compartment containing the cell element, which consists of positive and negative lead plates. These plates are insulated from each other by suitable separators (usually made of plastic, rubber, or glass) and submerged in a sulfuric acid electrolytic solution.

A variety of plates are used in the lead-acid battery—pasted plates, spun lead (Plante) plates, Gould plates, and ironclad plates. These plates are used to fulfill specific purposes.

Pasted plates, which are the most commonly used, are formed by applying lead-oxide pastes to a grid made of lead-antimony alloy. The grid is designed to give the plates mechanical strength, hold the active material in place, and provide adequate conductivity for the electric current created by the chemical action. The active material (lead oxide) is applied to the grids in paste form and allowed to dry. The plates are then put through an electrochemical process that converts the active material of the positive plates into lead peroxide, and that of the negative plates into sponge lead. This action is caused by immersing the plates in an electrolytic solution and passing a current through them in the proper direction. This type of plate is relatively light weight compared to plates that are more rugged and durable in construction.

After the plates are formed, they are built into positive and negative groups. The negative group of plates always has one more plate than the positive group so that both sides of the positive plates are acted upon chemically. This equalizes the expansion and contraction that takes place in the positive plates on both sides



Chemical action in a lead-acid cell

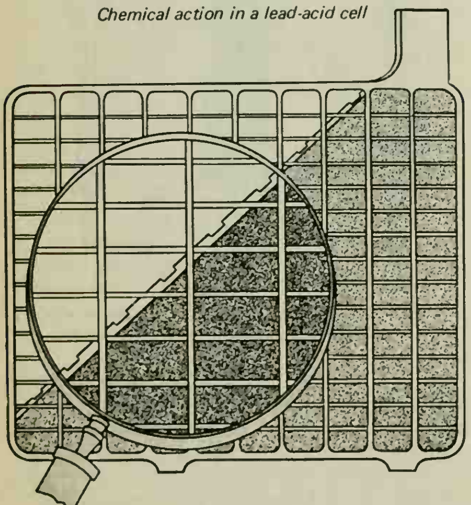


Plate showing a grid framework

and prevents buckling. These groups are then assembled with separators to produce cell elements. The separators are grooved vertically on one side and smooth on the other. The grooved side is placed next to the positive plate to permit free circulation of the electrolytic solution around the active material.

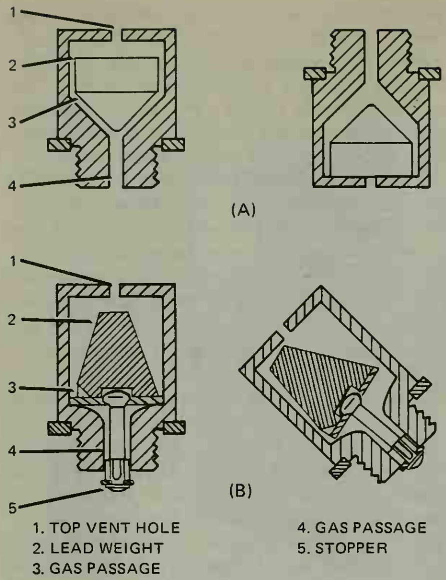
The positive plates, which are lead peroxide, and the negative plates, which are sponge lead, are referred to as the active material of the battery. However, these materials alone in a container will cause no chemical reaction unless there is a path for interaction between them. To provide this path and to carry the electric current in the battery are the functions of the electrolytic solution.

A battery container is the receptacle for the cells that make up the battery. Most containers are made from hard rubber, plastic, or bituminous material that is resistant to acid and mechanical shock and is able to withstand extreme weather conditions. Most batteries are assembled in a one-piece container with compartments for each individual cell. The bottom of the container has molded ribs to provide support for the elements and sediment space for the flakes of active material that drop off the plates during the life of the battery.

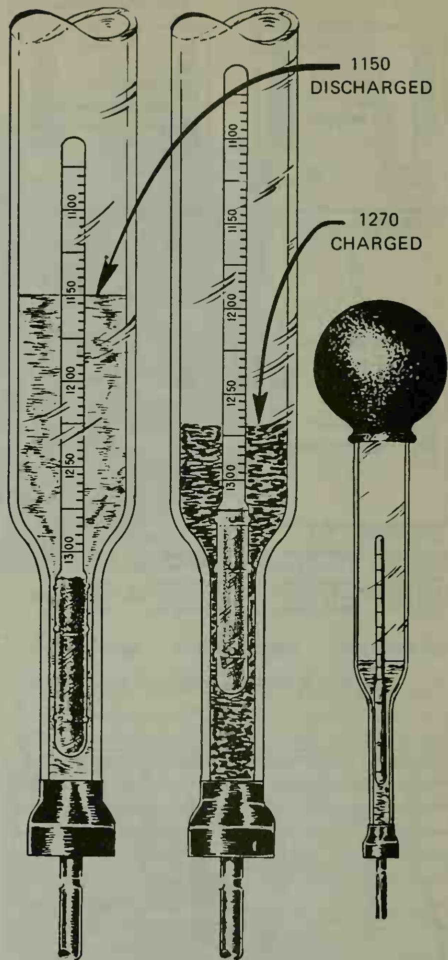
The battery, or cell, covers and the battery container are usually made of the same material. The cell covers provide openings for the two-element terminals and a vent plug.

Connectors are used to connect the cells of a battery in series. The element in each cell is placed so that the negative terminal of one cell is physically next to the positive terminal of the next cell; they are connected both physically and electrically by a cell connector. Connectors must be of sufficient size to carry the current demands of the battery without overheating.

Vent plugs, which are of various designs, function with the cover vent openings to permit the escape of gases that form within the cells and to prevent leakage or loss of the electrolytic solution. Some batteries utilize a nonspill vent plug, which makes it possible to place the battery in any position without loss of the solution. This type of vent plug is widely used in aircraft.



Nonspill vent plugs



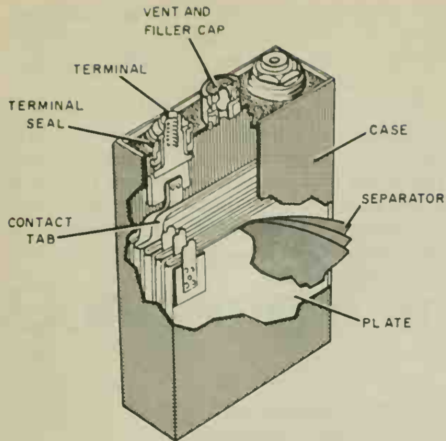
A type B hydrometer used to measure the specific gravity of the electrolyte

Sealing compound, generally made of a bituminous substance, is used to form a seal between the cell cover and the container. The compound is an acid-resistant material that must conform to rigid vibration and heat standards. This ensures that the sealing compound does not melt or flow at summer temperatures and does not crack at winter temperatures. Batteries with a polystyrene jar use a polystyrene cement as a sealer.

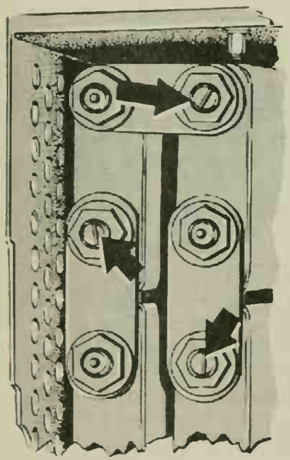
The terminals of a lead-acid battery are normally distinguishable from one another by their physical size and the manufacturer's marking. The positive terminal is marked with a plus (+) and is slightly larger than the negative terminal, marked with a minus (−).

Mixing Electrolytes

The electrolytic solution of a fully charged battery usually contains about 38 percent sulfuric acid by weight or about 27 percent by volume. In preparing the solution, distilled water and sulfuric acid are used. New batteries may be delivered with containers of concentrated sulfuric acid of 1,830 specific gravity or electrolyte of 1,400 specific gravity, both of which must be diluted with distilled water to make an electrolytic solution of the proper specific gravity. The container used for diluting the acid should be made of glass, earthenware, rubber, or lead.



A nickel-cadmium cell



Relief valves in the negative post of nickel-cadmium

When mixing the electrolytic solution, always pour acid into water; never pour water into acid. Pour the acid slowly and cautiously to prevent excessive heating and splashing. Stir the solution continuously with a nonmetallic rod to mix the heavier acid with the lighter water and to keep the acid from sinking to the bottom. When concentrated acid is diluted, the solution becomes very hot.

Nickel-Cadmium Batteries

Nickel-cadmium batteries are far superior to the lead-acid type. Some are physically and electrically interchangeable with the lead-acid type, while some are sealed units that use the standard plug and receptacle connections found on other electrical components. These batteries generally require less maintenance than lead-acid batteries throughout their service life; that is, they require less frequent additions of electrolyte or water.

The nickel-cadmium and lead-acid batteries have capacities that are comparable at normal discharge rates, but at high discharge rates the nickel-cadmium battery can:

1. Be charged in a short time.
2. Deliver a large amount of power.
3. Stay idle in any state of charge for an indefinite time and hold a full charge when stored for a long time.
4. Be charged and discharged any number of times without appreciable damage.

Furthermore, individual cells of a nickel-cadmium battery can be replaced if they wear out; the rest of the cells do not have to be replaced.

Silver-Zinc Batteries

Silver-zinc batteries are used largely in military applications and in some industrial applications where their unique characteristics are important enough to justify their comparatively high cost.

The silver-zinc battery was developed for one major and one secondary purpose. The major purpose was to secure a large quantity of electrical power for emergency operations. The secondary purpose was to permit lightweight design. A lightweight, silver-zinc battery provides as much electrical capacity as a much larger lead-acid or nickel-cadmium battery.

Operational silver-zinc batteries have a nominal operating voltage of 24 volts, obtained with sixteen 1.5 volt cells. Cell electrolytic

levels should be monitored and adjusted periodically. Other required operations that might be considered maintenance are normal recharging of the battery and keeping the top surfaces of the cells reasonably clean.

Silver-Cadmium Battery

One of the recent developments in storage batteries is the silver-cadmium battery. Generally, the most important requirements for evaluating and designing a battery are high energy density, good voltage regulation, long shelf life, repeatable number of cycles, and long service life. The silver-cadmium battery is designed to offer the overall maximum performance in all of these categories.

The silver-cadmium battery has more than twice the wet shelf life of the silver-zinc battery. This characteristic and its good voltage regulation make the silver-cadmium battery a highly desirable addition to the family of electric storage batteries. Limitations include lower cell voltage than other rechargeable batteries and high initial cost.

3
Conductors and Insulators

Basic electronics theory states that all matter is composed of atoms, and atoms are composed of subatomic particles called protons, electrons, and neutrons. In addition, all the moving electrons are tightly bound to the nucleus, except for those that revolve in the outer orbit. For example, the electrons in the outer orbits of aluminum atoms may move constantly from one atom to another in a haphazard manner. Electrons that are able to move in this fashion are known as free electrons. Furthermore, all matter is made up of positive and negative charges of electricity because of its atomic structure, and the atomic structure of a material determines whether or not it will have many or few free electrons.

If the haphazard flow of free electrons in a material is controlled so that they move from negative to positive simultaneously, we have electron flow, which forms an electric current.

CONDUCTORS

In general, all materials can be divided into two major categories, conductors and insulators. These categories are based on the ability of materials to allow an electric current to flow through them. This ability in turn depends on their atomic structure.

Materials that have large numbers of free electrons are good conductors. All metals are conductors of electricity to some extent, but some, such as silver, copper, and aluminum, are superior conductors. Silver is a better conductor than copper, but copper is more widely used because it is less expensive than silver. Aluminum is used as a conductor where weight is a major consideration, as in high-tension lines with long spans between supports. Usually these are stranded cables with a small steel wire core to provide the necessary tensile strength.

The ability of a material to conduct electricity also depends on its dimensions. Conductors may be in the form of bars, tubes, or sheets, but the most common form is wire. We are all familiar with the power lines that span the countryside. These lines, made of wire, conduct electricity from one place to another. They bring electric power into our homes to operate the lights and other electrical equipment. Many sizes of wire, from the fine, hairlike wire

used in the coils of sensitive measuring instruments to the large sizes used for carrying high-voltage current in electric power plants, are in use. Usually the ability of a conductor to carry electricity will vary directly with the area of its cross section. This relationship is due to the fact that more atoms are present in the larger area and therefore more free electrons are available.

Stranded wire is used when flexibility is necessary, as in the cords of lamps, electric irons, and toasters. To make wire easier to handle and to protect it from changes in weather and other external conditions, it is often covered with some other material, such as rubber, cotton, plastic, or enamel. These coverings, which provide protection against short circuits and current leakage, are known as insulators.

Copper vs. Aluminum Conductors

Although silver is the best conductor, its cost limits its use to special circuits where a substance with high conductivity is needed. The two most generally used conductors are copper and aluminum. Each metal has characteristics that make its use advantageous under certain circumstances. Likewise, each has certain disadvantages.

Copper has better conductivity than does aluminum, it is more ductile (capable of being drawn out), it has relatively high tensile strength, and it can be easily soldered. It is more expensive and heavier than aluminum.

Although aluminum has only about 60 percent of the conductivity of copper, its lightness allows long spans in power lines, and its relatively large diameter for a given conductivity reduces corona—that is, the discharge of electricity from the wire when it has a high potential. The discharge is greater when smaller diameter wire is used than when larger diameter wire is used. However, aluminum conductors are not easily soldered, and aluminum's relatively large size for a given conductance makes insulation costly.

INSULATORS

To be useful and safe, electric current must be forced to flow only where it is needed. It must be "channeled" from the power source to a useful load. In general, current-carrying conductors must not be allowed to come in contact with one another, their supporting hardware, or people working near them. To accomplish this, conductors are coated or wrapped with various materials generally referred to as insulators or insulating materials.

An insulator is a material, or combination of materials, in which the atomic structure precludes practically any movement of electrons from atom to atom. In other words, an insulator is a material that has few free electrons. No material known is a perfect insulator; there is no material through which electricity cannot be forced. But there are materials that are such poor conductors that for all practical purposes they prohibit electron flow. Porcelain, glass, air, dry wood, rubber, and oil are in this category.

One thing you must learn about electricity is that unless you are very careful when you handle it, you may have the unpleasant and dangerous experience of receiving a shock. Insulating materials are used so that electrical equipment can be handled safely. Insulators are also used to prevent current leakage and power losses.

Everyone has handled a common electric light bulb and knows what it looks like. Conducting and insulating materials are used in their construction. The electric current that heats the fine wire inside the bulb, called the filament, must flow through a series of conductors that eventually connect to a generating plant. If you were to touch a filament while it is carrying current, that is, when the bulb is lighted, you would get a shock or a burn. But we know that it is possible to insert and remove the bulb from the socket without injury by touching only the glass. The glass, even though it is indirectly in contact with the current-carrying filament, is not carrying an electric current; hence it must be an insulator. The brass threads and other metal parts on the base of the bulb are the contact points with the line and therefore must be conductors.

Two fundamental properties of insulation materials (for example, rubber, glass, asbestos, paper, and plastic) are insulation resistance

and dielectric strength. These are entirely different and distinct properties.

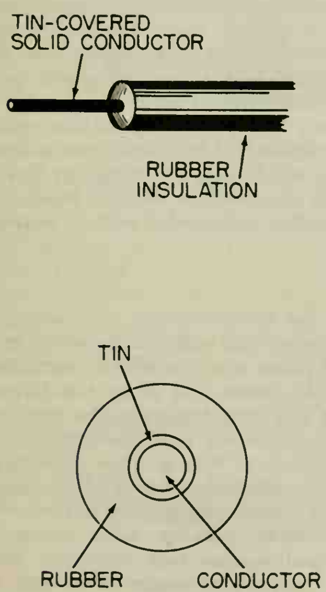
Insulation resistance is the resistance to current leakage through and over the surface of insulation materials. Insulation resistance can be measured without damaging the insulation, and information obtained from measurement serves as a useful guide in appraising the general condition of insulation. However, the data may not give a true picture of the condition of the insulation. Clean, dry insulation having cracks or other faults may show a high insulation resistance but would not be suitable for use.

Dielectric strength is the ability of the insulator to withstand potential difference and is usually expressed in terms of the voltage at which the insulation fails because of electrostatic stress. Maximum dielectric strength values can be measured by raising the voltage of a test sample until the insulation breaks down.

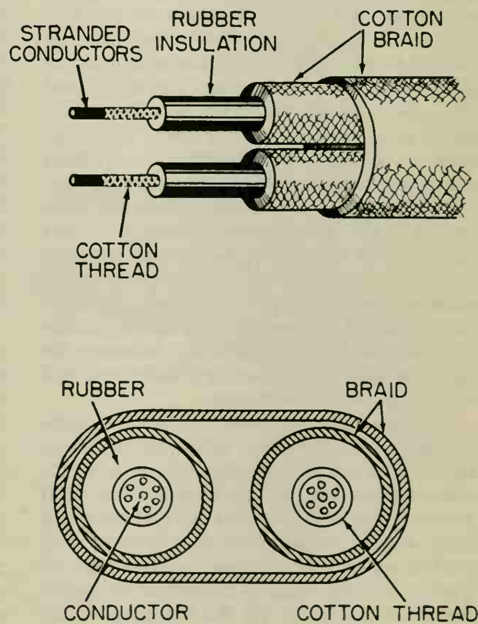
Rubber

One of the most common types of insulation is rubber. The voltage that may be applied to a rubber-covered pair of conductors (twisted pair) depends on the thickness and the quality of the rubber covering. Other factors being equal, the thicker the insulation, the higher the applied voltage can be. There are two types of rubber-covered wire. One is a single, solid conductor, and the other is a two-conductor cable in which each stranded conductor is covered with rubber insulation. In each case, the rubber serves the same purpose—to confine the current to its conductor.

A thin coating of tin separates the copper conductor from the rubber insulation. If the thin coating of tin were not used, chemical action would take place, and the rubber would become soft and gummy where it makes contact with the copper. When small, solid, or stranded conductors are used, a winding of



Rubber insulation on a solid conductor



Rubber insulation on a stranded conductor

cotton threads is applied between the conductors and the rubber insulation.

Plastics

Plastic has become one of the more common materials used as insulation for electrical conductors. It has good electrical resistance, flexibility, and moisture resistance under various conditions. Various types of plastics are used as insulating material; thermoplastic is one of the most common. With the use of thermoplastic, the conductor temperature can be higher than with some other types of insulating materials without damage to the insulating quality of the material.

Varnished Cambric

Heat is developed when current flows through a wire, and when a large amount of current flows, considerable heat may be developed. The heat can be dissipated if air is circulated freely around the wire. If a cover of insulation is used, the heat is not dissipated so readily and the temperature of the wire may become very high. Rubber is a good insulator at relatively low voltage as long as the temperature remains low, but too much heat will cause even the best grade of rubber insulation to become brittle and crack. Varnished cambric insulation will withstand much higher temperatures than will rubber insulation.

Varnished cambric insulation is cotton cloth tape that has been coated with an insulating varnish. The tape is wound around the conductor in layers, and an oily compound is applied between the layers. This compound prevents water from seeping through the insulation. It also acts as a lubricant between the layers of tape so that they will slide over each other when the cable is bent.

This type of insulation is used on high-voltage conductors used with switch gear in substations and powerhouses and in other locations subjected to high temperatures. It is also used on high-voltage generator coils and leads and on transformer leads because it is unaffected by oils or grease and has high dielectric strength. Varnished cambric and paper insulation for cables are the two types of insulating materials most widely used at voltages above 15,000 volts, but such cables are always lead-covered to keep out moisture.

Asbestos

Even varnished cambric may break down when the temperature goes above 85° C. (185° F.). When the combined effects of high ambient (surrounding) temperature and high internal temperature due to heavy current flow through a wire raise the temperature of the wire above 85° C., asbestos insulation is used.

Asbestos is a good insulation for wires and cables used under conditions that produce very high temperatures. It is fire resistant and does not change with age. One type of asbestos-covered wire consists of a stranded copper conductor covered with felted asbestos, which is in turn covered with asbestos braid. This type of wire is used in motion-picture projectors, arc lamps, spotlights, heating element leads, and so forth.

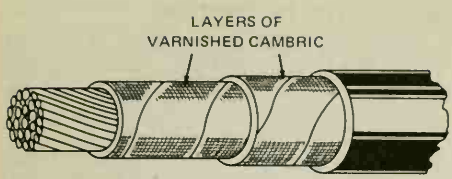
Another type of asbestos-covered cable is used in leads for motors and transformers that sometimes must operate in hot, wet locations. Varnished cambric covers the inner layer of felted asbestos and prevents moisture from reaching that layer. Asbestos loses its insulating properties when it becomes wet and in fact becomes a conductor. Although this combination insulation will withstand some moisture, it should not be used on conductors that may be partly immersed in water at times unless the insulation is protected with an outer lead sheath.

Paper

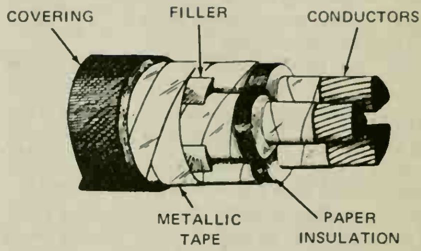
Paper has little insulation value alone, but when impregnated with a high grade of mineral oil, it serves as a satisfactory insulation for high-voltage cables. The oil has high dielectric strength and tends to prevent the breakdown of paper insulation when the paper is thoroughly saturated with it. Thin paper tape is wrapped in many layers around the conductors, and it is then soaked with oil.

Some three-conductor cable consists of paper insulation on each conductor with a spirally wrapped nonmagnetic metallic tape over the insulation. The space between conductors is filled with a suitable spacer to

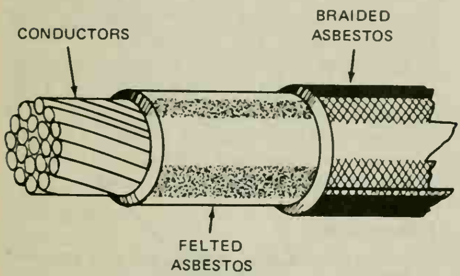
INSULATION



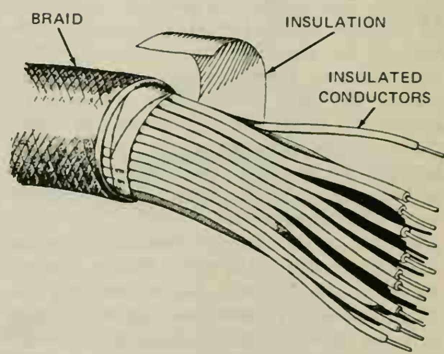
Varnished cambric insulation



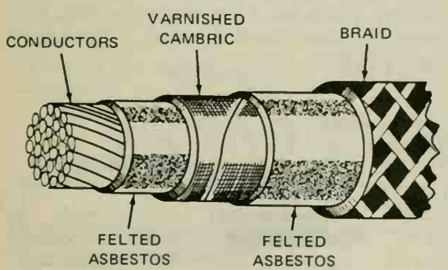
Paper-insulated power cables



Asbestos insulation



Silk and cotton insulation



Asbestos and varnished cambric insulation

round out the cable, and another nonmagnetic metal tape is used to secure the entire cable. Then a lead sheath is applied overall. This type of cable is used at voltages from 10,000 to 35,000 volts.

Silk and Cotton

Certain types of circuits (for example, communications circuits) require a large number of conductors—perhaps several hundred. In a cable containing many conductors, each conductor often is insulated from the others by silk and cotton threads.

The use of silk and cotton as insulation keeps the size of the cable small enough to be handled easily. The silk and cotton threads are wrapped around the individual conductors in reverse directions, and the covering is then impregnated with a special wax compound.

Because the insulation in this type of cable is not subjected to high voltage, thin layers of silk and cotton are used.

Enamel

The wire used on the coils of meters, relays, small transformers, and so forth is called magnet wire, and it is insulated with an enamel coating. The enamel is a synthetic compound of cellulose acetate (wood pulp and magnesium). In the manufacturing process, the bare wire is passed through a solution of the hot enamel and then cooled. This process is repeated six to ten times. Enamel has higher dielectric strength than rubber, but it is not practical for large wires because of the expense and because the insulation is readily fractured when large wires are bent.

Enamel is the thinnest insulating coating that can be applied to wires. Hence, enamel-insulated magnet wire makes smaller coils. Enameled wire is sometimes covered with one or more layers of cotton covering to protect the enamel from nicks, cuts, or abrasions.

Because of the expense of insulation and its stiffening effect on wire and because of the great variety of physical and electrical conditions in which conductors are operated, only the necessary minimum of insulation is applied to cables designed for specific jobs. Therefore there is a wide variety of insulated conductors available to meet the requirements of the job with minimum loss of flexibility.

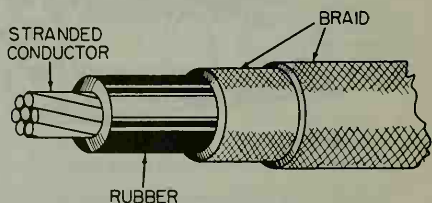
CONDUCTOR PROTECTION

Wires and cables are generally subject to abuse. The type and amount of abuse depends on how and where they are installed and the manner in which they are used. Cables buried directly in the ground must resist moisture, chemical action, and abrasion. Wires installed in buildings must be protected against mechanical injury and overloading. Wires strung on pole crossarms are kept far enough apart so that they do not touch, but snow, ice, and strong winds necessitate the use of conductors having high tensile strength and substantial supporting frame structures.

Generally, except for overload transmission lines, wires or cables are protected by some form of covering. The covering may consist of an insulating material such as rubber or plastic. Over this an outer covering of fibrous braid may be applied. If conditions require it, a metallic outer covering may be used. The type of outer covering used depends on how and where the wire or cable is to be used.

Fibrous Braid

Cotton, linen, silk, rayon, and jute are used in fibrous braid protective coverings. These outer coverings provide protection under conditions where insulated wires or cables are not exposed to mechanical injury. Interior wiring for lights or power is usually done with impregnated-cotton, braid-covered, rubber-insulated wire. Generally, the wire will be further protected by a flame-resistant nonmetallic outer covering or by a flexible or rigid conduit.



Fibrous braid protective covering

In a typical building wire, two braid coverings are used for extra protection. The outer braid is soaked with a compound that resists moisture and flame.

Impregnated cotton braid is used as a covering for outdoor overhead conductors to afford protection against abrasion. For example, the service wires from transformer secondary mains to the house service entrance and the high-voltage primary mains to the transformer are protected in this manner.

Lead Sheath

Subway-type cables or wires that are continually subjected to water must be protected by a watertight cover, which is usually a continuous lead jacket or a rubber sheath molded around the cable.

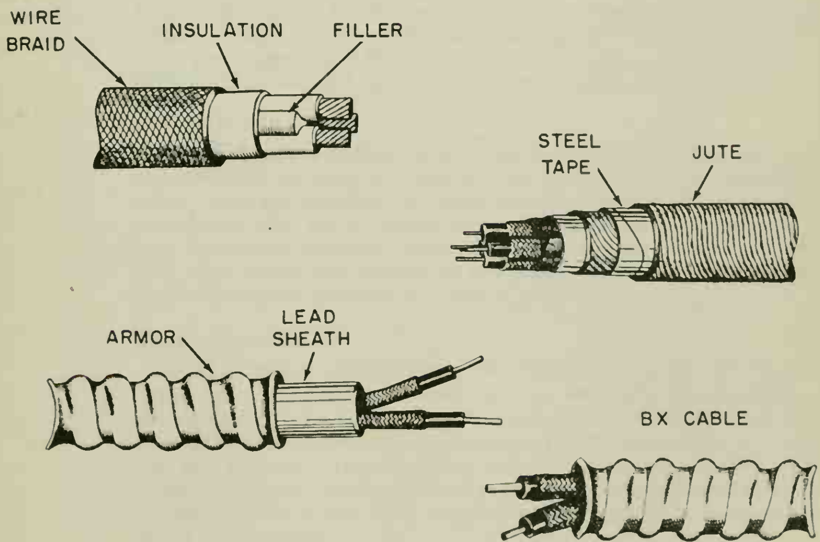
An example of a lead-sheathed cable used in power work would be a stranded three-conductor type. Each conductor is insulated and then wrapped with a layer of rubberized tape. The conductors are twisted together and a filler or rope is added to form a rounded core. Over this is wrapped a second layer of tape called the serving, and finally the lead sheath is molded around the cable.

Metallic Armor

Metallic armor provides a tough protective covering for wires or cables. The type, thickness, and kind of metal used to make the armor depend on the use of the conductors, on the circumstances under which the conductors are to be used, and on the amount of rough treatment expected.

There are four types of metallic armor cables. Wire braid armor is used wherever light, flexible protection is needed. The individual wires that are woven together to form the metal braid may be made of steel, copper, bronze, or aluminum. Besides mechanical protection, the wire braid also presents a static shield.

When cables are buried directly in the ground, they may be subject to moisture and abrasion. They are protected from moisture by a lead sheath and from abrasion by steel



Metallic armor

tape or interlocking armor covers. The steel tape is wrapped around the cable and then covered with a serving of jute. It is known as Parkway cable. The interlocking armor covering can withstand impact better than the steel tape. Interlocking armor also has other uses. In wiring buildings, interlocking armor-covered wire (BX cable) without the lead sheath is frequently used. The wires in the BX cable may be protected against chafing by a fiber sheath.

Wire armor is the best type of covering to withstand severe wear and tear. Underwater leaded cable usually has an outer wire armor cover.

4
Tools and Equipment

The electrical apparatus and materials that an electrician is required to install and maintain require the use of special hand tools.

PLIERS

Pliers are furnished with either insulated or uninsulated handles. Although pliers with insulated handles are always used in working on or near "hot" wires, they must not be considered sufficient protection alone; other precautions must be taken. Long-nose pliers are used for close work in panels or boxes. Wire clippers are used to cut wire to size. One type of wire clipper has a plastic cushion in the cutting head that grips the clipped wire end and prevents the clipped piece from flying about and causing personal injury. The slip-joint pliers are used to tighten locknuts or small nuts on devices.

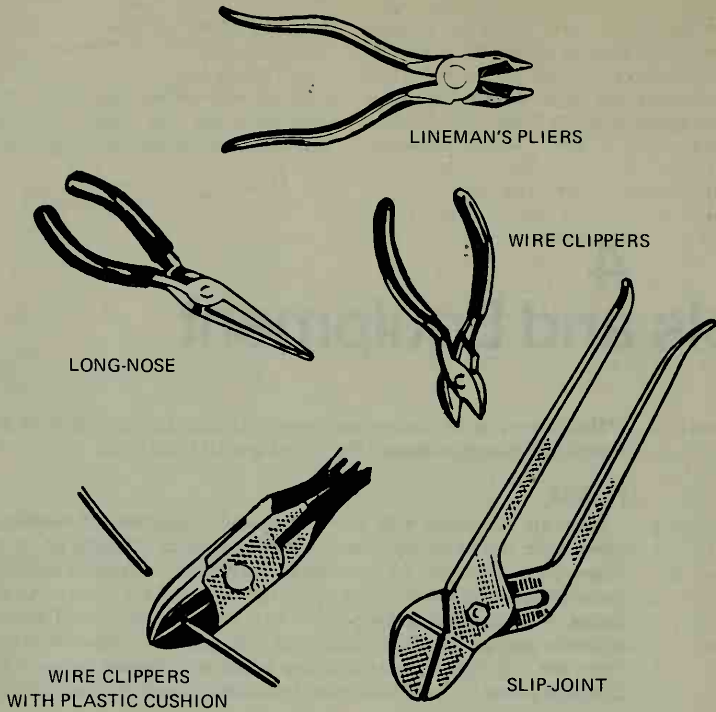
FUSE PULLER

The fuse puller is designed to eliminate the danger of pulling and replacing cartridge fuses by hand. It is also used for bending fuse clips, adjusting loose cutout clips, and handling live electrical parts. One type of fuse puller, made of molded plastic, has an electric circuit encased in the handle. This fuse puller is similar to a voltmeter, except that the indicating device is a neon glow tube. Test probes are attached to the handle of the fuse puller and can be used to determine if voltage is present in a circuit.

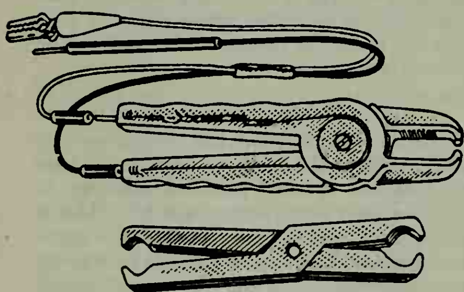
SCREWDRIVERS

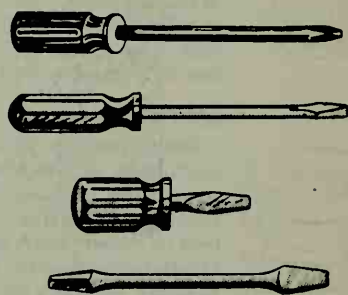
Screwdrivers are made in many sizes with different tips. Those used by electricians should have insulated handles. Generally the electrician uses screwdrivers in attaching electrical devices to boxes and attaching wires to terminals. One variation of the screwdriver is the screwdriver bit, which is held in a brace and is used for heavy-duty work. For safe and efficient application, screwdriver tips should be kept free of damage and should be selected to match the screw slot. Most worn screwdriver tips may be restored quickly with a file or grinder.

Electrical appliances may require the use of Phillips-head screwdrivers of different sizes. When these become worn or damaged, throw them away.



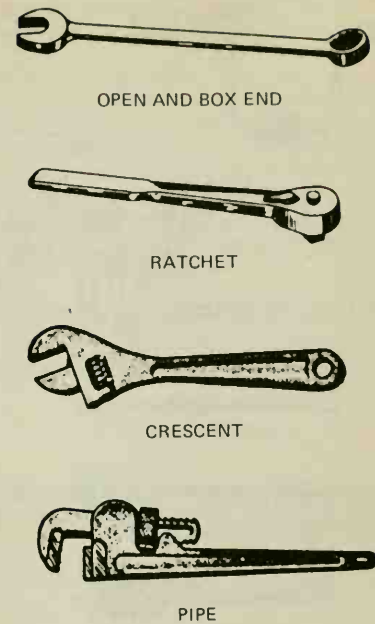
Pliers


Fuse pullers


Screwdrivers

WRENCHES

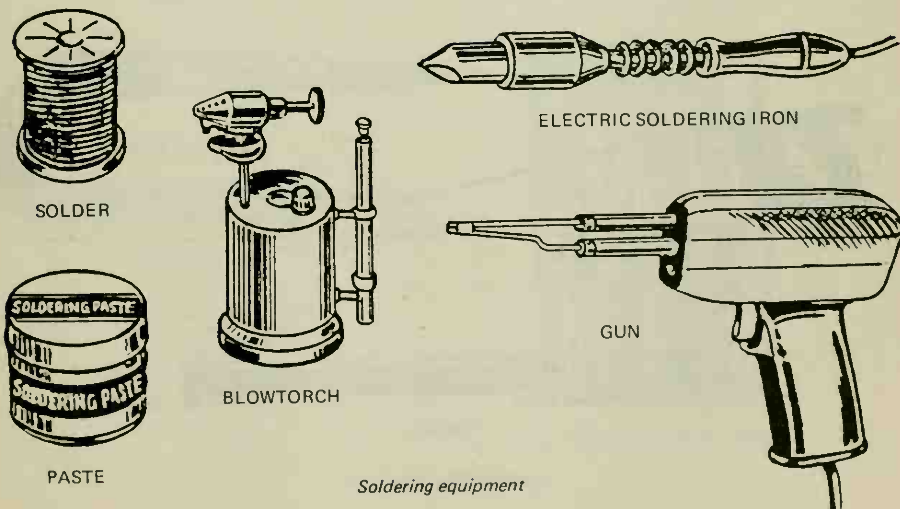
There are four types of wrenches used by electricians. Adjustable open-end wrenches, commonly called crescent wrenches, open-end, closed-end, and socket wrenches are used on hexagonal and square fittings, such as machine bolts, hexagon nuts, or conduit unions. Pipe wrenches are used for pipe and conduit work and should not be used where crescent, open-end, closed-end, or socket wrenches can be used. Their construction will not permit the application of heavy pressure on square or hexagonal material, and the continued misuse of the tool in this manner will deform the teeth on the jaw faces and mar the surfaces of the material being worked.



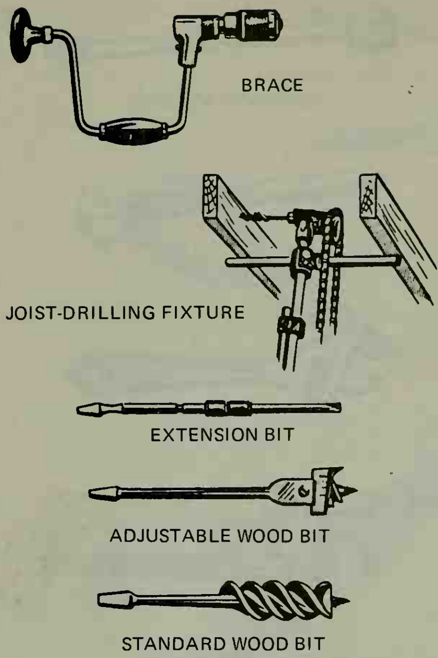
Wrenches

SOLDERING EQUIPMENT

A standard soldering kit used by electricians consists of nonelectric or electric soldering irons or both, a blowtorch (for heating a nonelectric soldering iron and pipe or wire joints), a spool of solid tin-lead wire solder or flux-core solder, and soldering paste. An alcohol or propane torch can be used in place of the blowtorch. Acid-core solder should never be used in electrical wiring.



Soldering equipment



Drilling equipment

DRILLING EQUIPMENT

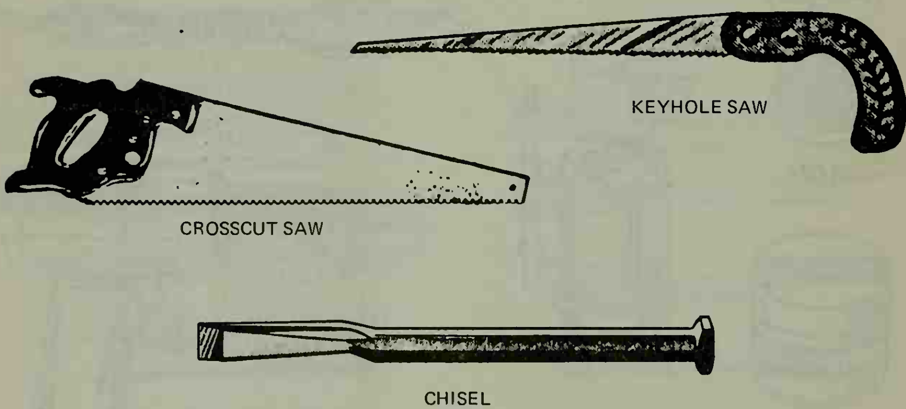
Drilling equipment consists of a brace, a joist-drilling fixture, an extension bit to allow for drilling into and through deep cavities, an adjustable bit, and a standard wood bit. These are required in electrical work to drill holes in building structures for the passage of conduit or wire in new or modified construction. Similar equipment is required for drilling holes in sheet-metal cabinets and boxes. In this case high-speed electric drills should be used. Carbide drills are used for tile or concrete work.

WOODWORKING TOOLS

The crosscut and keyhole saws and wood chisels are used by electricians to remove wooden structural members obstructing a wire or conduit run and to notch studs and joists to take conduit, cable, or box-mounting brackets. They are also used in the construction of wood-panel mounting brackets. The keyhole saw may again be used to cut openings in walls of existing buildings where boxes are to be added.

METALWORKING TOOLS

Cold chisels, center punches, and several other types of metalworking tools are used



Woodworking equipment

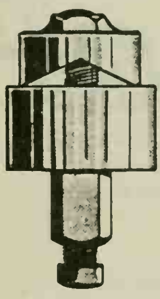
when working on steel panels. The knockout punch is used either in making or enlarging a hole in a steel cabinet or outlet box. The hacksaw is usually used by an electrician to cut conduit, cable, or wire too large for wire cutters. In using the hacksaw, a light, steady stroke of about forty to fifty times a minute is best. A new blade should always be inserted with the teeth pointing away from the handle. The tension wing nut must be tightened until the blade is rigid. Insufficient tension will cause the blade to twist and jam, whereas too much tension will cause the blade to break. Blades have 14, 18, 24, and 32 teeth per inch. The best blade for general use is one with 18 teeth per inch. A blade with 32 teeth per inch is best for cutting thin material. The mill file is used in filing the sharp ends of cutoffs.

MASONRY DRILLS

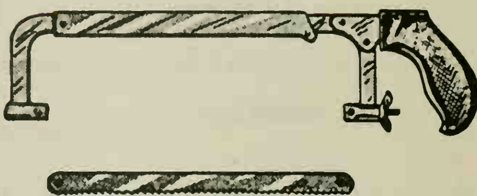
An electrician should have several sizes of masonry drills in his tool kit. These normally are carbide-tipped and are used to drill holes in brick or concrete walls either for anchoring apparatus with expansion screws or for the passage of conduit or cable. The carbide-tipped bit may be used with a power drill and a hand-operated masonry drill.

CONDUIT THREADERS AND DIES

Rigid conduit is normally threaded for installation. With one type of conduit threader



KNOCKOUT PUNCH

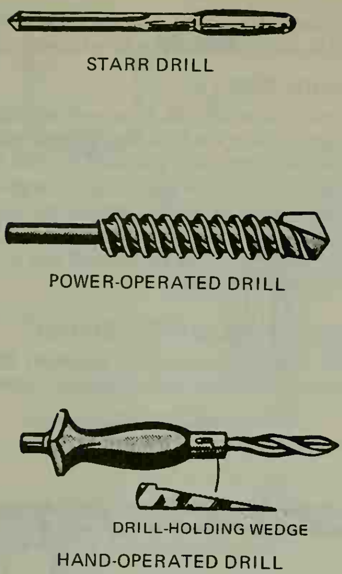


HACKSAW AND BLADE

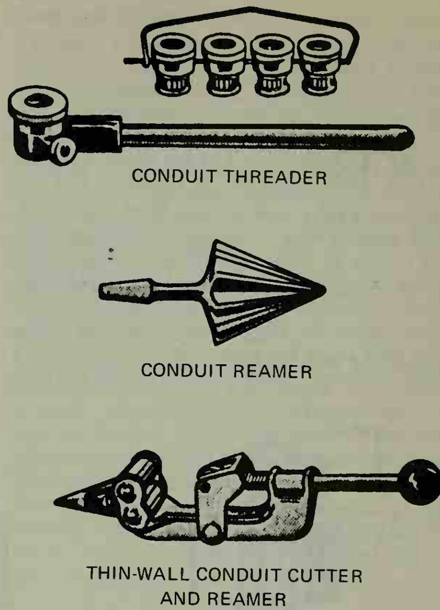
MILL FILE

COLD CHISELS AND PUNCHES

Metalworking equipment



Masonry drills



Conduit tools

and with dies used in cutting pipe threads on conduit, the tapered pipe reamer is used to ream the inside edge of the conduit as a precaution against wire damage. The conduit cutter is used when cutting thin-wall conduit. It has a tapered blade attachment for reaming the conduit ends.

KNIVES AND OTHER INSULATION-STRIPPING TOOLS

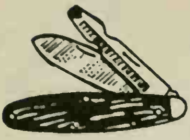
Wire and cable insulation is stripped or removed with a variety of different tools. Knives and patented wire strippers are used to bare the wire of insulation before making connections. Scissors are used to cut insulation and tape. A multipurpose tool designed to cut and skin wires, attach terminals, gauge wire, and cut small bolts may also be used. An armored cable cutter may be used instead of a hacksaw in removing the armor from the electrical conductors at a box entry or when cutting the cable to length.

HAMMERS

Hammers are used either in combination with other tools such as chisels or in nailing equipment to building supports. Tools such as a carpenter's claw hammer and a machinist's ball peen hammer can be advantageously used by electricians in their work.

TAPE

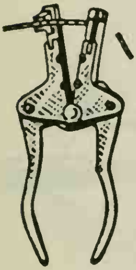
Various types of tape are used to replace insulation and wire coverings. Friction tape is a cotton tape impregnated with an insulating adhesive compound. It provides weather resistance and limited mechanical protection to a splice already insulated. Rubber or varnished cambric tape may be used as an insulator when replacing wire covering. Plastic electrical tape is made of a plastic material with adhesive on one face. It has replaced friction and rubber tape in the field for 120- and 208-volt circuits, and it serves a dual purpose in taping joints. It is preferred over the former methods.



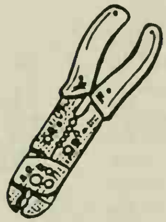
ELECTRICIAN'S KNIFE

ELECTRICIAN'S SCISSORS

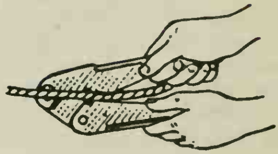
SKINNING KNIFE



STRIPPER

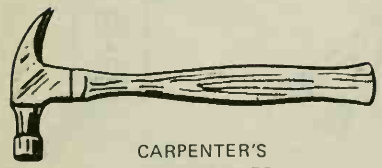


MULTIPURPOSE TOOL



CABLE CUTTER

Insulation-stripping tools



CARPENTER'S CLAW HAMMER

MACHINIST'S BALL-PEEN HAMMER

Hammers

FISH WIRE AND DROP CHAIN

Fish wires are used primarily to pull wires through conduits. Many pulls are quite difficult and require a fish-wire "grip" to obtain adequate force on the wire in pulling. The fish wire is made of tempered spring steel about $^1/_4$ inch wide and is available in lengths to suit requirements. It is stiff enough to preclude bending under normal operation but can be pushed or pulled easily around bends or conduit elbows.

When pulling wires and cables in existing buildings, an electrician will normally employ a fish wire or drop chain between studs. A drop chain consists of small chain links attached to a lead or iron weight. It is used only to feed through wall openings in a vertical plane.

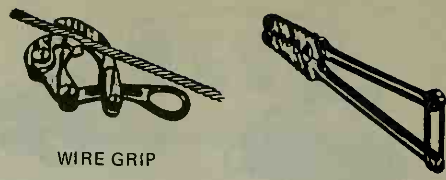
RULER AND MEASURING TAPE

As an aid in cutting conduit to exact size as well as in determining approximate material

quantities required for each job, the electrician should be equipped with a folding rule and a steel tape.

WIRE CLAMPS AND GRIPS

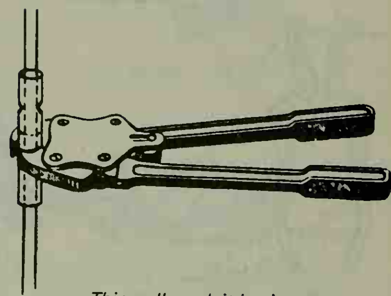
To pull wire through conduit and to pull open-wire installations tight, the wire grip is an invaluable aid. The wire grip has been designed so that the harder the pull on the wire, the tighter the wire will be gripped. The splicing clamp is used to twist the wire pairs into a uniform and tight joint when making splices.



Wire grip and splicing clamp

THIN-WALL CONDUIT IMPINGER

When indenter couplings and connectors are used with thin-wall conduit, an indenter tool (impinger) must be used to attach these fittings permanently to the conduit. This tool has points that, when pressed against the fitting, form indentations in the fitting and press into the wall of the tubing to hold the fitting on the conduit. The use of these slip-on fittings and the impinger materially reduces the installation time required and thus reduces the cost of thin-wall conduit installations.


Thin-wall conduit impinger

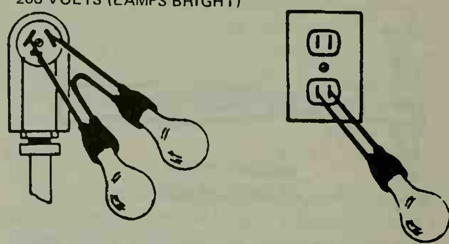
WIRE CODE MARKERS

Tapes with identifying numbers or nomenclature are available for permanently identifying wires and equipment. These are particularly valuable in helping to identify wires in complicated wiring circuits, in circuit breaker panels, or in junction boxes.

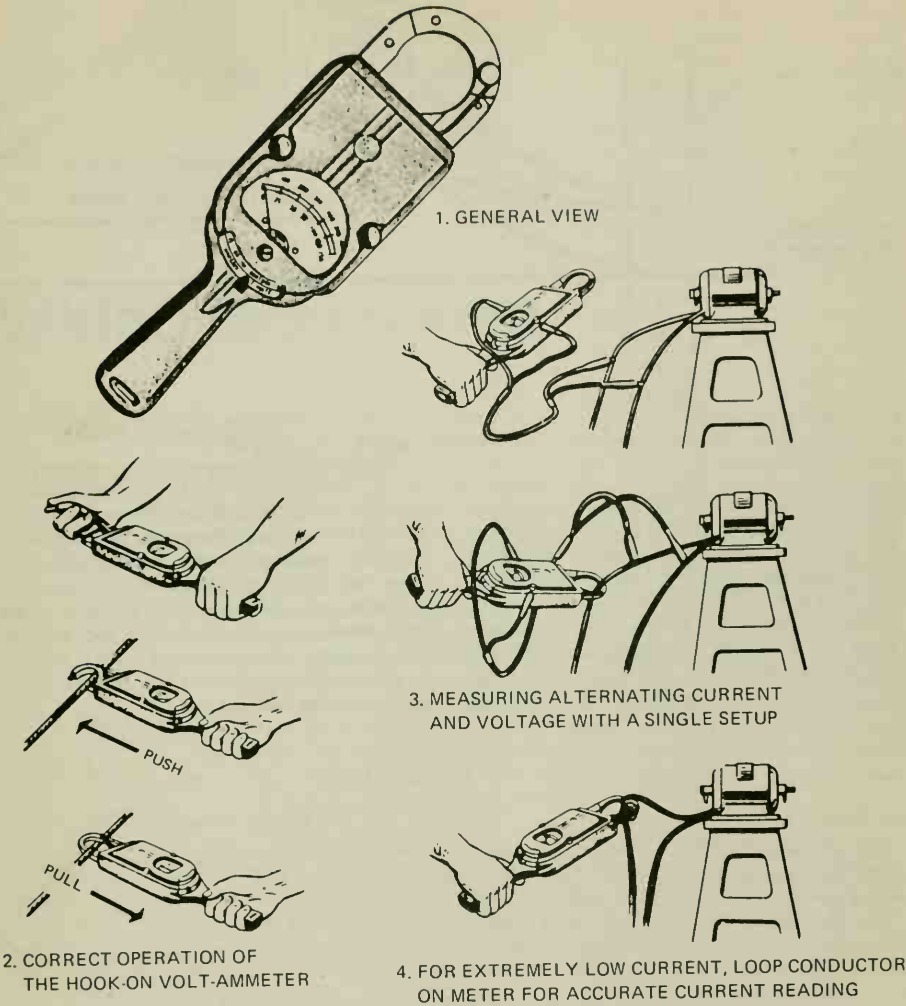
METERS AND TEST LAMPS

An indicating voltmeter or a test lamp is useful for determining system voltage or locating ground leads, and for testing circuit continuity through the power source. Both devices have a light that glows when current passes through them. A test lamp is used as a voltage indicator.

A modern method of measuring current flow in a circuit uses the hook-on volt-ammeter which does not need to be hooked into the circuit. In making a measurement, the hook-on section is opened by hand, and the meter is placed against the conductor. A slight push on the handle snaps the section shut; a pull springs open the hook on the C-shaped current transformer and releases the conductor. Voltage can be measured using the hook-on section. With three coils around the meter, the current reading will be three times the actual current flowing through the wire. To obtain



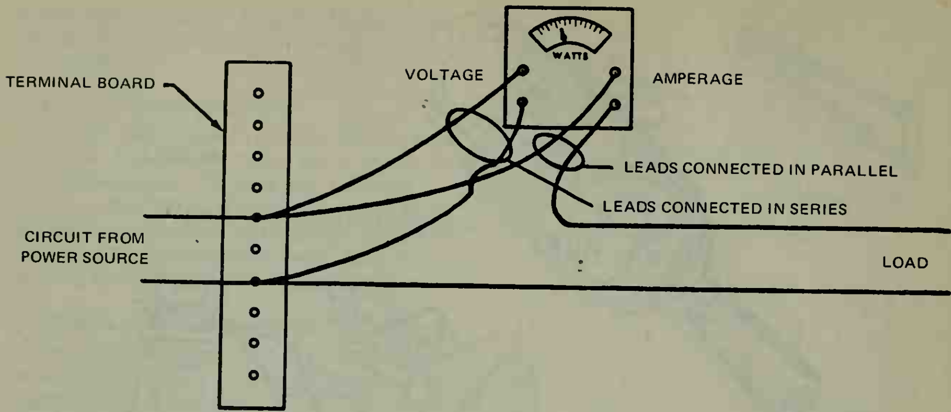
Test lamps



Hook-on volt-ammeter

the true current, therefore, this reading is divided by three. The hook-on volt-ammeter can be used only on alternating current circuits and can measure current only in a single conductor.

The basic unit of measurement for electric power is the watt. For electric devices used by domestic consumers of electricity, the wattage rating signifies that when energized at normal line voltage, the apparatus will use electricity



Wattmeter connection

at the specified rate. In alternating-current circuits, power is the product of three quantities: the potential (volt), the current (amperes), and the power factor (percent). Power is measured by a wattmeter. This instrument is connected so that the current in the measured circuit flows through the stationary field coils in the wattmeter, and the voltage across the measured circuit is impressed on the wattmeter armature circuit, which includes movable coils and a fixed resistor. The power factor is automatically included in the measurement because the torque developed in the wattmeter is always proportional to the product of the instantaneous values of current and voltage. Consequently, the instrument gives a true indication of the power, or the rate at which energy is being utilized.

5
Wiring Techniques

A wire is a slender rod or filament of drawn metal. The definition restricts the term to what would ordinarily be understood as solid wire. The word *slender* is used because the length of a wire is usually great in comparison with the diameter. If a wire is covered with insulation, it is properly called an insulated wire. Although the term *wire* refers to the metal, it is generally understood to include the insulation.

A conductor is a wire or combination of wires not insulated from one another, suitable for carrying an electric current. A stranded conductor is a conductor composed of a group of wires or of any combination of groups of wires. The wires in a stranded conductor are usually twisted together.

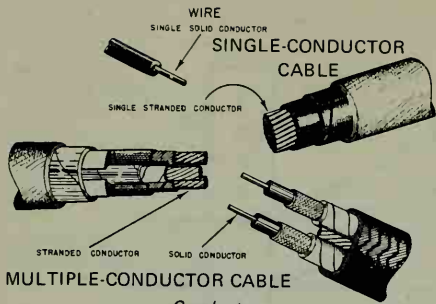
A cable is either a stranded conductor (single-conductor cable) or a combination of conductors insulated from one another (multiple-conductor cable). The term cable is a general one, and in practice it is usually applied only to the larger sizes of conductors. A small cable is more often called a stranded wire or cord. Cables may be bare or insulated. The insulated cables may be sheathed (covered) with lead or protective armor.

WIRE SIZES

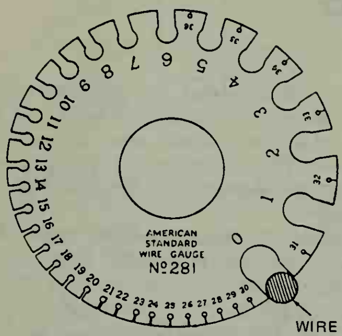
Wire sizes are denoted by the use of the American Wire Gauge (AWG) standards. The largest gauge size is No. 0000. Wires larger than this are classified in size by their circular mil cross-sectional area. One circular mil is the area of a circle with a diameter of $^1/_{1000}$ of an inch. The most common wire sizes used in interior wiring are 14, 12, and 10. They are usually solid. Some characteristics of the numbering system follow.

1. As the numbers become larger, the size of the wire decreases.
2. The sizes normally used have even numbers.
3. No. 8 and No. 6 wires, which are furnished either solid or stranded, are normally used for heavy-duty circuits or as service-entrance leads to buildings. Wire sizes larger than these are used for extremely heavy loads and for pole-line distributions.

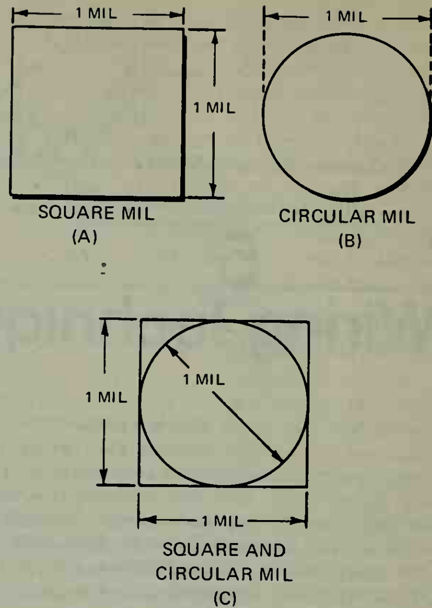
Several factors must be considered in selecting the size of wire to be used for transmitting and distributing electric power.



Conductors



Wire gauge



A: square mil; B: circular mil;
C: comparison of circular to square mil

One factor is the allowable power loss in the line. This loss represents electrical energy converted into heat. The use of large conductors will reduce the resistance and therefore the power loss. However, large conductors are more expensive initially than small ones. They are also heavier, and they require more substantial supports.

A second factor is the permissible voltage drop in the line. If the power source maintains a constant voltage at the input to the line, any variation in the line load will cause a variation in the line current, and a consequent variation in the voltage drop in the line. A wide variation in the voltage drop in the line causes poor voltage regulation at the load. A reduction in load current lowers the amount of power being transmitted, whereas a reduction in line resistance increases the size and weight of conductors required. A compromise is generally reached between voltage variation and the weight of line conductors.

A third factor is the current-carrying ability of the line. When current is drawn through the line, heat is generated. The temperature of the line will rise until the heat radiated or otherwise dissipated is equal to the heat generated by the passage of current through the line. If the conductor is insulated, the heat generated in the conductor is not so readily dissipated as it would be if the conductor were not insulated. Thus, to protect the insulation from too much heat, the current through the conductor must be maintained below a certain value. Rubber insulation will begin to deteriorate at relatively low temperatures. Varnished cloth insulation retains its insulating properties at higher temperatures. And other insulation, for example, asbestos or silicone, is effective at still higher temperatures.

Electrical conductors may be installed in locations where the ambient (surrounding) temperature is relatively high, in which case the heat generated by external sources constitutes an appreciable part of the total heat in the conductor. Due allowance must be made for the influence of external heating on the allowable conductor current, and each case has its own specific limitations. The maximum allowable operating temperature of insulated conductors varies with the type of conductor insulation being used.

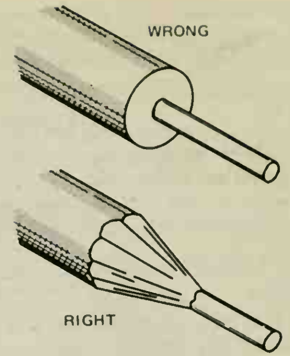
CONDUCTOR SPLICES AND TERMINAL CONNECTIONS

Conductor splices and connections are an essential part of any electric circuit. When conductors join each other or connect to a load, splices or terminals must be used. It is important that they be properly made, since any electric circuit is only as good as its weakest link. The basic requirement of any splice or connection is that it be both mechanically and electrically as strong as the conductor or device with which it is used. High-quality workmanship and materials must be employed to ensure lasting electrical contact, physical strength, and insulation (if required). The most common methods of making splices and connections in electric cables are discussed here.

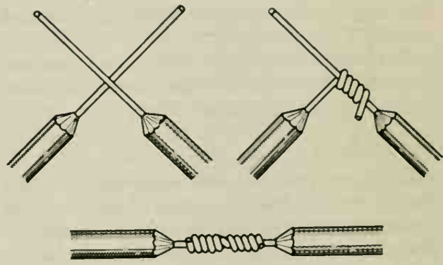
The first step in making a splice is to prepare the wires, or the conductor. Insulation must be removed from the end of the wire, and the exposed metal must be cleaned. To remove the insulation from the wire, use a sharp knife in much the same manner as you would in sharpening a pencil. That is, hold the knife blade at an acute angle to the wire to avoid nicking the wire. This produces a tapered cut on the insulation. The insulation may also be removed by using a plierslike hand-operated wire stripper. After the insulation is removed, the bare wire ends should then be scraped bright with the back of a knife blade or rubbed clean with fine sandpaper.

Western Union Splice

Small, solid conductors can be joined together by a simple connection known as the Western Union splice. In most instances the wires can be twisted together with the fingers and the ends clamped into position with a pair of pliers.



Removing insulation from a wire


Western Union splice

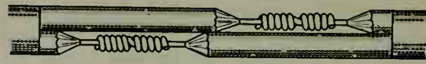
First, prepare the wires for splicing by removing sufficient insulation and cleaning the conductor. Next, bring the wires to a crossed position and make a long twist or bend in each wire. Then wrap one of the wire ends four or five times around the straight portion of the wire. Wrap the other end wire in a similar manner. Finally, press the ends of the wires down as close as possible to the straight portion of the wire; this precaution prevents the sharp ends from puncturing the tape covering that is wrapped over the splice.

Staggered Splice

Joining small, multiconductor cables presents a slight problem. Each conductor must

be spliced and taped, and if the splices are directly opposite each other, the overall size of the joint becomes large and bulky. A smoother and less bulky joint can be made by staggering the splices.

A two-conductor cable can be joined to a similar cable by means of the staggered splice. Exercise care to ensure that a short wire is connected to a long wire and that the sharp ends are clamped firmly down on the conductor.

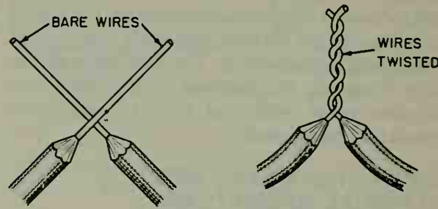


Staggered splice

Rattail Joint

Wiring that is installed in buildings is usually placed inside long lengths of steel pipe (conduit). Whenever branch circuits are required, junction or pull boxes are inserted in the conduit. One type of splice that is used for branch circuits is the rattail joint.

The ends of the conductors to be joined are stripped of insulation. The wires are then twisted to form the rattail effect.

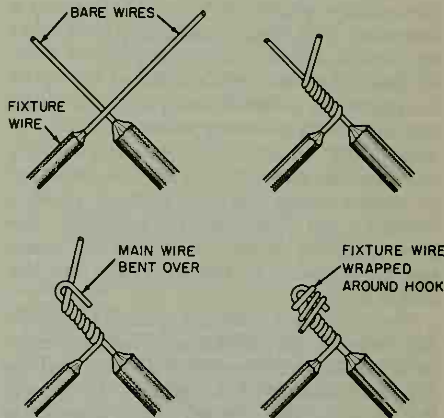


Rattail joint

Fixture Joint

A fixture joint is used to connect a light fixture to the branch circuit of an electrical system where the fixture wire is smaller in diameter than the branch wire. Like the rattail joint, it will not stand much mechanical strain.

The first step is to remove the insulation from the wires to be joined. After preparing the wires, wrap the fixture wire a few times around the branch wire. The wires are not twisted as in the rattail joint. Bend the end of the branch wire over the completed turns. Then wrap the remainder of the bare fixture wire over the bent branch wire. Soldering and taping completes the job.



Fixture joint

Knotted Tap Joint

All of the splices considered up to this point are known as butted splices. Each was made by joining the free ends of the conductors together. Sometimes, however, it is necessary to join a conductor to a continuous wire. Such a junction is called a tap joint.

From the main wire, to which the branch wire is to be tapped, remove about one inch of insulation. Strip the branch wire of about three inches of insulation. Cross the branch wire over the main wire with about three-fourths of the bare portion of the branch wire extending above the main wire. Bend the end of the branch wire over the main wire, then bring it under the main wire, around the branch wire, and then over the main wire to form a knot. Wrap it around the main conductor in short, tight turns and trim off the end.

The knotted tap is used where the splice is subject to strain or slip. When there is no mechanical strain, the knot may be eliminated.

SOLDERING EQUIPMENT

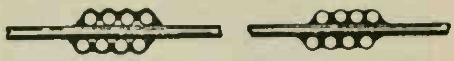
Soldering operations are a vital part of electrical and electronics maintenance procedures. Soldering is a manual skill that can and should be learned by anyone who works in the field of electricity. Practice is required to develop proficiency in the techniques of soldering; however, practice serves no useful purpose unless it is founded on a thorough understanding of basic principles. This discussion is devoted to providing information regarding some important aspects of soldering operations.

Both the solder and the material to be soldered must be heated to a temperature which allows the solder to flow. If either is heated inadequately, "cold" solder joints result. Such joints do not provide either the physical strength or the electrical conductivity required. Appreciably exceeding the flow point temperature, however, is likely to cause damage to the parts being soldered. Various types of solder flow at different temperatures. In soldering operations it is necessary to select a solder that will flow at a temperature low enough to avoid damage to the part being soldered, or to any other part or material in the immediate vicinity.

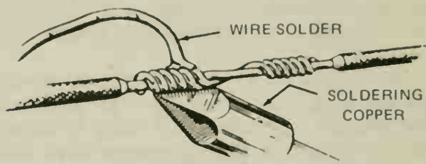
The duration of high heat conditions is almost as important as the temperature. Insulation and many other materials in electrical equipment are susceptible to damage from heat. They will be damaged if they are exposed to excessively high temperatures. They will deteriorate if they are exposed to less drastically elevated temperatures for prolonged periods. The time and temperature limitations depend on many factors, such as the kind and amount of metal involved, cleanliness, the ability of the material to withstand heat, and the heat transfer and dissipation characteristics of the surroundings.

Solder

The three grades of solder generally used for electrical work are 40-60, 50-50, and 60-40 solder. The first figure is the percentage of tin, and the second is the percentage of lead. The higher the tin content, the lower the temperature required for melting. Also, the higher the tin content, the easier the flow, the less time



Right and wrong solder joint



Application of solder

required to harden, and generally the easier it is to do a good soldering job.

In addition to the solder, there must be flux to remove any oxide film on the metals being joined, otherwise they cannot fuse. The flux enables the molten solder to wet the metals so the solder can stick. The two types of flux are acid flux and rosin flux. Acid flux is more active in cleaning metals but is corrosive. Rosin is always used for the light soldering work in making wire connections. Generally, the rosin is in the hollow core of solder intended for electrical work, so that a separate flux is unnecessary. Such rosin-core solder is the type generally used. It should be noted, though, that the flux is not a substitute for cleaning the metals to be soldered. The metal must be shiny clean for the solder to hold.

Soldering Process

Cleanliness is a prime prerequisite for efficient, effective soldering. Solder will not adhere to dirty, greasy, or oxidized surfaces. Heated metals tend to oxidize rapidly, and the oxide must be removed prior to soldering. Oxides, scale, and dirt can be removed by mechanical means (such as scraping or cutting with an abrasive) or by chemical means. Grease or oil films can be removed by a suitable solvent. Cleaning should be accomplished just before the actual soldering operation.

Items to be soldered should normally be tinned before a mechanical connection is

made. When the surface has been properly cleaned, a thin, even coating of flux can be placed over the surface to be tinned to prevent oxidation while the part is being heated to soldering temperature. Rosin core solder is usually preferred in electrical work, but a separate rosin flux may be used instead. Separate rosin flux is frequently used for tinning wires in cable fabrication. Tinning is the coating of the material to be soldered with a light coat of solder.

The tinning on a wire should extend only far enough to take advantage of the depth of the terminal or receptacle. Tinning or solder on wires subject to flexing causes stiffness and may result in breakage.

The tinned surfaces to be joined should be shaped and fitted, then mechanically joined for good mechanical and electrical contact.

Soldering Tools

The important tools for soldering are soldering irons, the soldering gun, and the pencil iron. Also discussed here are the resistance soldering set and other soldering aids.

Soldering irons: All high-quality irons operate in the temperature range of 500° to 600° F. Even the little 25-watt midget irons produce this temperature. The important difference in iron sizes is not temperature but thermal inertia (the capacity of the iron to generate and maintain a satisfactory soldering temperature while giving up heat to the joint to be soldered). Although it is not practical to try to solder a heavy metal box with the 25-watt iron, that iron is quite suitable for replacing a half-watt resistor in a printed circuit. An iron with a rating as large as 150 watts would be satisfactory for use on a printed circuit, if suitable soldering techniques are used.

Some irons have built-in thermostats. Others are provided with thermostatically controlled stands. These devices control the temperature of the soldering iron but are a source of trouble. A well-designed iron is self-regulating by virtue of the fact that the resistance of its element increases with rising temperature, thus limiting the flow of current. For critical work, it is convenient to have a variable transformer for fine adjustment of heat, but for general-purpose work, no temperature regulation is needed.

Soldering gun: The soldering gun has gained great popularity in recent years because it heats and cools rapidly. It is especially well adapted to maintenance and troubleshooting work where only a small part of the technician's time is spent actually soldering. A soldering iron, if kept hot constantly, oxidizes rapidly and is therefore difficult to keep clean.

A transformer in the soldering gun supplies approximately one volt at high current to a loop of copper that serves as the tip. It heats to soldering temperature in three to five seconds but may overheat to the point of incandescence if left on over thirty seconds. The gun is operated with a finger switch so that it heats only when the switch is depressed.

Since the gun normally operates only for short periods at a time, it is comparatively easy to keep clean and well tinned so that little oxidation occurs. However, the tip is made of pure copper and is susceptible to pitting, which results from the dissolving action of the solder.

The gun or iron should always be kept tinned to permit proper heat transfer to the work being soldered. Tinning also provides adequate control of the heat to prevent thermal spillover to nearby materials. Tinning the tip of a gun may be somewhat more difficult than tinning the tip of an iron. Maintaining the proper tinning on either, however, is easier with silver solder.

Pitting of the tip indicates the need for retinning. Before you do this, however, file away a portion of the tip. Retinning too often results in using up the tip too fast.

Overheating can easily occur when you use the gun to solder delicate wiring. With practice, however, you can accurately control the heat by pulsing the gun on and off.

Heating and cooling cycles tend to loosen the nuts or screws that hold the replaceable tips on soldering irons or guns. When the nut on a gun is loosened, the resistance of the tip connection increases, and the temperature of the connection rises. Continued loosening may eventually cause an open circuit; therefore, the nut should be tightened periodically.

Resistance soldering: A time-controlled resistance soldering set is now available. The set consists of a transformer that supplies 3 or 6 volts at high current to stainless steel or carbon tips. The transformer is turned on by a foot switch and off by an electronic timer. The timer can be adjusted for as much as three seconds soldering time. This set is especially useful for soldering cables to plugs and similar connectors—even the smallest types available.

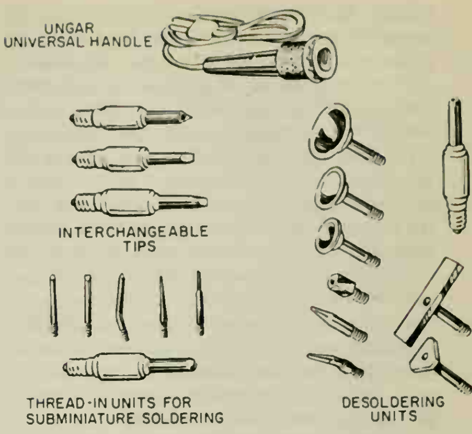
In use, the double-tip probes of the soldering unit are adjusted to straddle the connector cup to be soldered. One pulse of current heats it for tinning and, after the wire is inserted, a second pulse of current completes the job. Since the soldering tips are hot only during the brief period of actual soldering, burning of wire insulation and melting of connector inserts are greatly minimized.

The greatest difficulty with this device is keeping the probe tips free of rosin and corrosion. A cleaning block is mounted on the transformer case for this purpose. Some technicians prefer fine sandpaper for cleaning the double tips. Caution: Do not use steel wool. It is dangerous when used around electrical equipment.

Pencil iron and special tips: An almost indispensable item is the pencil soldering iron with an assortment of tips. Miniature soldering irons, with wattage ratings under 40 watts are easy to use and are recommended. In an emergency, larger irons can be converted and used on subminiature equipment.

One type of iron is equipped with several different tips that range from one-fourth to one-half inch in diameter and are of various shapes. This equipment makes it adaptable to a variety of jobs. Unlike most tips, which are held in place by setscrews, these tips are threaded, and they screw into the barrel. This feature provides excellent contact with the heating element, thus improving the efficiency of heat transfer. A pad of "antiseize" compound is supplied with the iron. Apply this compound to the threads each time you install a tip in the iron so that you can easily remove the tip later when you want to insert another tip.

A special feature of this iron is the soldering pot that screws in like a tip and holds about a thimbleful of solder. It is useful for tinning the ends of a large number of wires.



Pencil soldering iron kit with special tips

The interchangeable tips are of various sizes and shapes for specific applications. Extra tips can be bought and shaped to serve special purposes. The thread-in units are useful in soldering subminiature items. The desoldering units are specifically designed for performing special and individual functions.

Another advantage of the pencil soldering iron is its possible use as an improvised light source for inspections. Simply remove the soldering tip and insert a 120-volt, 6-watt, type 6S6, candelabra bulb into the socket.

If leads, tabs, or small wires are bent against a board or terminal, the slotted tips of the pencil iron can be used to simultaneously melt the solder and straighten the leads.

A hollow tip, which fits over a pin terminal, can be used to desolder and resolder wiring at cables or feed-through terminals.

Many miniature components have multiple connections, all of which must be desoldered to permit removal of the component in one operation. These connections can be desoldered individually by heating each connection and brushing away the solder. In using this method, take particular care to ensure that loose solder does not stick to other parts or become lodged where it may cause a short

circuit. A more efficient method is to use the specially shaped desoldering units. Select a tip of the proper size and shape that will contact all terminals to be desoldered—and nothing else. Do not permit the tip to remain in contact with the terminals too long at one time.

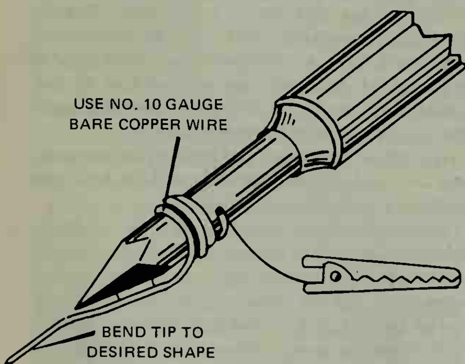
If no suitable tip is available for a particular operation, you can improvise a tip. Wrap a length of copper wire around one of the regular tips and bend the wire into the proper shape for the purpose. This method also serves to reduce tip temperature when a larger iron must be used on miniature components.

In the use of the pencil iron, the selection of solder and flux is also critical. A small-diameter rosin-core solder with a high tin-lead ratio (60-40) is normally preferred in miniature circuits where heat is critical.

Soldering aids: Several devices other than the soldering iron and its tips are required in soldering miniature circuits. Several of these (brushes, probes, scrapers, knives, etc.) have been mentioned previously.

Some type of thermal shunt is essential in all soldering operations that involve heat-sensitive components. Pliers, tweezers, or hemostats may be used for some applications, but their effectiveness is limited. A superior heat shunt permits soldering the leads of component parts without overheating the part itself.

For maximum effectiveness, any protective coating should be removed before applying the heat shunt. The shunt should be attached carefully to prevent damage to the leads, terminals, or component parts. The shunt should be clipped to the lead, between the joint and the part being protected. As the joint is heated, the shunt absorbs the excess heat before it can reach the part and cause damage.



Improvised tip to reduce tip temperature

A small piece of beeswax may be placed between the protected unit and the heat shunt. When the beeswax begins to melt, the temperature limit has been reached. The heat source should be removed immediately, but the shunt should be left in place.

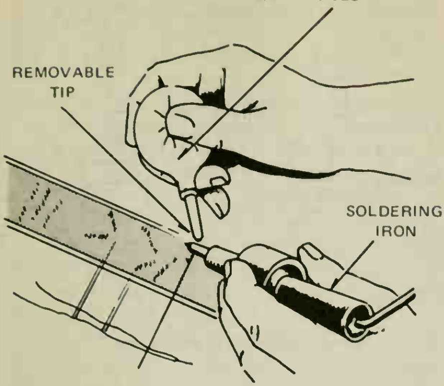
Premature removal of the heat shunt permits the unrestricted flow of heat from the melted solder into the component. The shunt should be allowed to remain in place until it cools to room temperature. A clip-on shunt is preferable because positive action is needed to remove the shunt but it does not have to be held in place.

Another invaluable soldering aid is the "solder-sucker" syringe. Its purpose is to "suck up" excess solder (and incidentally the excess heat) from a joint. The only requirements of an efficient solder sucker are a controllable source of vacuum (squeeze bulb), a solder receiver, and a tip. The tip must be able to withstand the heat of molten solder. A Teflon tip is ideal, but it may be difficult to acquire. A silicone-rubber-covered fiberglass sleeving with an inner diameter of 0.162 inch and the bulb from a medicine dropper can be used to make a suitable syringe. (The glass or plastic tip of the medicine dropper cannot withstand the heat.)

SOLDER CONNECTIONS

Frequent arguments occur in electrical shops concerning the proper method of making soldered connections to terminals and binding posts. For many years it was considered necessary to wrap the lead tightly around the terminal to provide maximum mechanical support and strength. This practice since has been found unnecessary.

Electronics Laboratories tested many standard capacitors and resistors soldered to terminals of various types. The joints were then subjected to vibrations far in excess of those



Solder sucker

normally encountered in electrical and electronic equipment. The connections were made with various degrees of wrapping around the terminals, with the main reliance for physical strength being placed on the solder. Wrappings of three-eighths to three-fourths turn are usually recommended so that the joint need not be held during the application and cooling of the solder.

Excessive wrapping of leads results in increased heat during soldering, more strain on parts, greater difficulty in inspection, greater difficulty in assembly and disassembly of the joints, and increased breakage of parts or terminals during desoldering operations. Insufficient wrapping may result in poor solder joints due to movement of the lead during the soldering operation.

The areas to be joined must be heated to or slightly above the flow temperature of the solder. The application of heat must be carefully controlled to prevent damage to components of the assembly, insulation, or nearby materials. Solder is then applied to the heated area. Only enough solder should be used to make a satisfactory joint. Heavy fillets or beads must be avoided.

Solder should not be melted with the soldering tip and allowed to flow onto the joint. The joint should be heated and the solder applied to the joint. When the joint is adequately heated, the solder will flow evenly. Excessive temperature tends to carbonize flux, thereby hindering the soldering operation.

No liquid should be used to cool a solder joint. With use of the proper tools and soldering techniques, a joint should not become so hot that rapid cooling is needed.

If for any reason a satisfactory joint is not made initially, the joint must be taken apart, the surfaces cleaned, excess solder removed, and the entire soldering operation (except tinning) repeated.

After the joint has cooled, all flux residues should be removed. Any flux residue remaining on the surface of an electrical contact may collect dirt and promote arcing later. This cleaning is necessary even when rosin-core solder is used.

Connections should never be soldered or desoldered while equipment power is on or while the circuit is under test. Always discharge any capacitors in the circuit before any soldering operation.

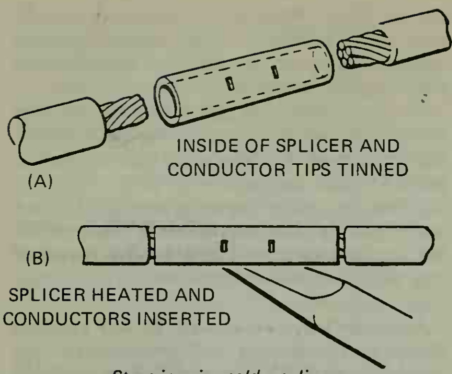
Solder Splicers

The solder splicer is essentially a short piece of metal tubing. Its inside diameter is just large enough to allow the tip of a stranded conductor to be inserted in either end after the conductor tip has been stripped of insulation.

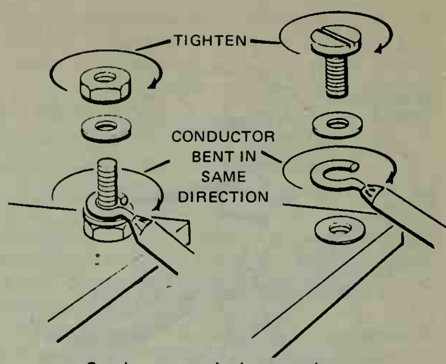
The splicer is first heated and filled with solder. While still molten, the solder is then poured out, leaving the inner surfaces tinned. When the conductor tips are stripped, the exposed strands should be long enough so that the insulation butts against the splicer when the conductors are tinned and fully inserted. When heat is applied to the connection and the solder melts, excess solder will be squeezed out through the vents. This must be cleaned away. After the splice has cooled, insulating material must be wrapped or tied over the joint.

Solder Terminal Lugs

In addition to being joined or spliced to one another, conductors are often connected to other objects, such as motors and switches. Since this is where a length of conductor ends



Steps in using solder splicer



Conductor terminal connection

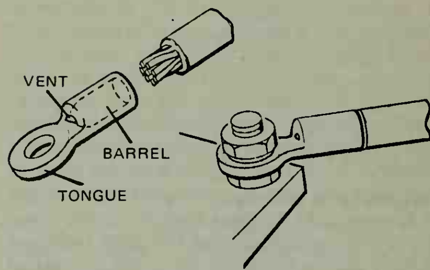
(terminates), such connections are referred to as terminal points. In some cases, it is allowable to bend the end of the conductor into a small "eye" and put it around a terminal binding post. Where a mounting screw is used, the screw is passed through the eye. The conductor tip that forms the eye should be bent. When the screw or binding nut is tightened, it also tends to tighten the conductor eye.

Sometimes this method of connection is not desirable. When design requirements are more rigid, terminal connections are made by using special hardware devices called terminal lugs. Terminal lugs are available in many different sizes and shapes, but all are essentially the same.

Each type of lug has a barrel (sleeve) that is wedged, crimped, or soldered to its conductor. There is also a tongue with a hole or slot in it to receive the terminal post or screw. When mounting a solder terminal lug to a conductor, first tin the inside of the barrel. Strip and tin the conductor tip and then insert it in the preheated lug. When mounted, the conductor insulation should butt against the lug barrel so that none of the conductor is exposed.

SOLDERLESS CONNECTORS

Splicers and terminal lugs that do not require solder are more widely used than those that do require solder. Solderless connectors are attached to their conductors by means of several different devices, but the principle of each is essentially the same. They are all squeezed (crimped) tightly onto their conductors. They afford adequate electrical contact and great mechanical strength. In addition, solderless connectors are easier to mount correctly because they are free from the most common problems of solder connections—namely, cold solder joints, burned insulation, and so forth.



Solder terminal lug

Solderless connectors are made in a great variety of sizes and shapes and for many different purposes. Only a few are discussed here.

Solderless Splicers

Three of the most common types of solderless splicers, classified according to their methods of mounting, are the split-sleeve, split-tapered-sleeve, and crimp-on splicers.

Split-sleeve splicer: To connect a split-sleeve splicer to its conductor, first insert the tip of

the stripped conductor between the split-sleeve jaws. With a tool designed for that purpose, the slide ring is forced toward the end of the sleeve. The sleeve jaws close tightly on the conductor, and the slide ring secures them.

Split-tapered-sleeve splicer: In mounting a split-tapered-sleeve splicer, the conductor is stripped and inserted in the split-tapered sleeve. The threaded sleeve is turned or screwed into the tapered bore of the body. As the sleeve is turned in, the split segments are squeezed tightly around the conductor by the narrowing bore. The finished splice must be covered with insulation.

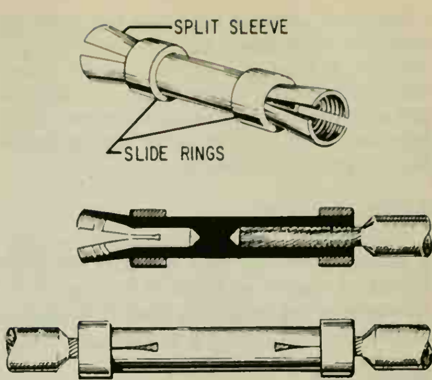
Crimp-on splicer: The crimp-on splicer is the simplest of the splicers discussed. These splicers are mounted with a special plierslike hand-crimping tool designed for that purpose. The stripped conductor tips are inserted in the splicer, which is then squeezed tightly closed. The insulating sleeve grips the outer insulated conductor, and the metallic internal splicer grips the bare conductor strands.

Solderless Terminal Lugs

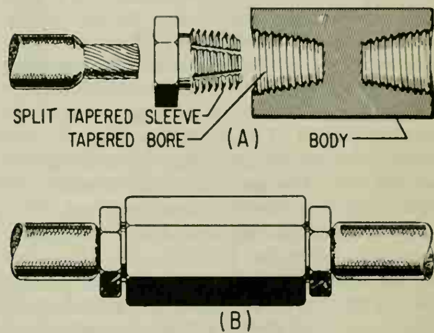
Solderless terminal lugs are used more widely than solder terminal lugs. There are many sizes and shapes of these lugs, each intended for a different type of service or conductor size. Only a few are discussed here. These are classified according to their method of mounting. They are the wedge-on split-tapered-sleeve, threaded split-tapered-sleeve, and crimp-on terminal lugs.

Wedge-on split-tapered-sleeve terminal lug: This type of lug is commonly referred to as a wedge-on lug because of the way it is secured to a conductor. The stripped conductor is inserted through the hole in the split sleeve. When the sleeve is forced, or wedged, down into the barrel, its tapered segments are squeezed tightly around the conductor.

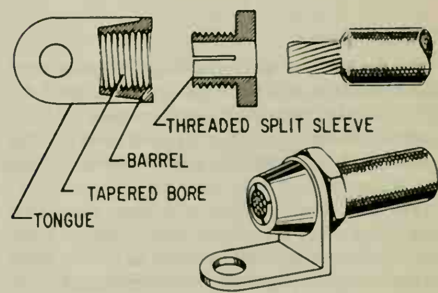
Threaded split-tapered-sleeve terminal lug: This lug is attached to a conductor in exactly the same manner as a split-sleeve splicer. The segments of the threaded split sleeve squeeze tightly around the conductor as it is turned into the tapered bore of the barrel. For this reason, the lug is commonly referred to as a screw wedge.



Split-sleeve splicer



Split-tapered-sleeve splicer



Threaded split-tapered-sleeve terminal lug

Crimp-on terminal lug: This lug is simply squeezed, or crimped, tightly onto a conductor. This is done by using the same tool used with the crimp-on splicer. Both preinsulated and uninsulated types are manufactured. When mounted, both the conductor and its insulation are gripped by the lug.

TAPING A SPLICE

The final step in completing a splice or joint is placing insulation over the bare wire. The insulation should be made of the same basic substance as the original insulation. Usually a rubber splicing compound is used.

Rubber Tape

Latex (rubber) tape is a splicing tape. It is used where the original insulation was rubber. The tape is applied to the splice with a light tension so that each layer presses tightly against the one underneath it. Pressure causes the tape to blend into a solid mass, making the restored insulation similar to the original.

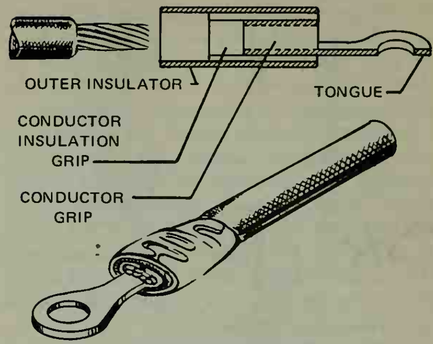
Between each layer of latex tape in the roll, there is a layer of paper or treated cloth. This layer prevents the latex from fusing while still on the roll. The paper or cloth is peeled off and discarded before the tape is applied.

The rubber splicing tape should be applied smoothly and under tension so that there are no air spaces between the layers. In putting on the first layer, start near the middle of the joint instead of the end. The diameter of the completed insulated joint should be somewhat greater than the overall diameter of the original insulated cable.

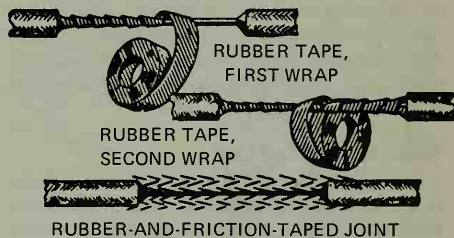
Friction Tape

Putting rubber tape over a splice means that the insulation has been restored to a great degree, but it is also necessary to restore the protective covering. Friction tape is used for this purpose; it also affords a minor degree of electrical insulation.

Friction tape is made of cotton cloth that has been treated with a sticky rubber compound. It comes in rolls similar to rubber tape, except that no paper or cloth separator is used between the layers. Friction tape is applied like rubber tape, but it does not stretch.



Crimp-on terminal lug



Rubber and friction tape insulation

The friction tape should slightly overlap the original braid covering. Wind the tape so that each turn overlaps the one before it, and extend the tape over onto the braid covering at the other end of the splice. From this point, wind a second layer back along the splice to the starting point. Cut the tape and firmly press down the end to complete the job.

Plastic Electrical Tape

Plastic electrical tape has come into wide use in recent years. It has certain advantages over rubber and friction tape. For example, it will withstand higher voltages for a given thickness. Single thin layers of certain commercially available plastic tape will stand several thousand volts without breaking down. However, to provide an extra margin of safety, several layers are usually wound over a splice.

6
Circuit Protection and Control Devices

Electricity is a vital part of contemporary American life. When it is not properly controlled, electricity can be dangerous and destructive. It can destroy components or complete units. It can cause injuries and even death.

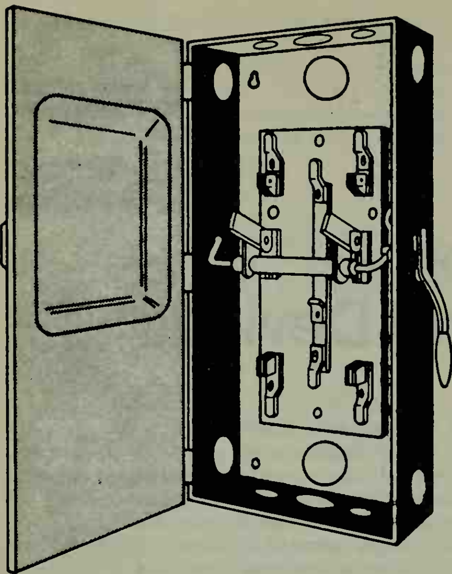
It is of the greatest importance, then, that all necessary precautions be taken to protect electrical circuits and units and to keep electricity under proper control at all times. In this chapter some of the devices that have been developed to protect and control electrical circuits are discussed.

When an electrical unit is built, the greatest care is taken to ensure that each separate electrical circuit is fully insulated from all others so that the current in a circuit will follow its intended unique path. Once the unit is in service, however, many things can happen to alter the original circuitry. Some of these changes can cause serious troubles if they are not detected and corrected in time.

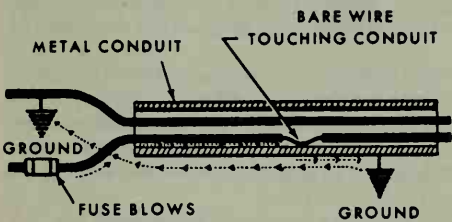
Perhaps the most serious trouble that can be found in a circuit is a direct short. This term is used to describe a situation in which some point in the circuit, where full system voltage is present, comes in direct contact with the ground or return side of the circuit. This establishes a path for current flow that contains no resistance other than that present in the wires carrying the current, and these wires have very little resistance.

According to Ohm's Law, if the resistance in a circuit is extremely low, the current will be extremely high. When a direct short occurs, then, there will be an extremely heavy current flowing through the wires. Suppose, for instance, that the two leads from a battery to a motor came in contact with each other. Not only would the motor stop running because of the current going through the short, but also the battery would become discharged quickly (perhaps ruined), and there would be danger of fire.

The battery cables in our example would be very large wires capable of carrying very heavy currents. Most wires used in electrical circuits are considerably smaller, and their current-carrying capacity is quite limited. The size of the wires used in any given circuit is determined by the amount of current the wires are expected to carry under normal operating conditions. Any current flow greatly in excess of normal, such as there would be in the case of a direct short, would cause rapid generation of heat.



Service switch box



A short circuit or ground

If the excessive current flow caused by the short is left unchecked, the heat in the wire will continue to increase until something gives way. Perhaps a portion of the wire will melt and open the circuit so that nothing is damaged other than the wires involved. The probability exists, however, that much greater damage would result. The heat in the wires could char and burn the insulation around the shorted wires and that of other wires bundled with them and cause more shorts. If a fuel or oil leak is near any of the hot wires, a disastrous fire might start.

To protect electrical systems from damage and failure caused by excessive current, several kinds of protective devices are installed in the systems. Fuses, circuit breakers, and thermal protectors are used for this purpose.

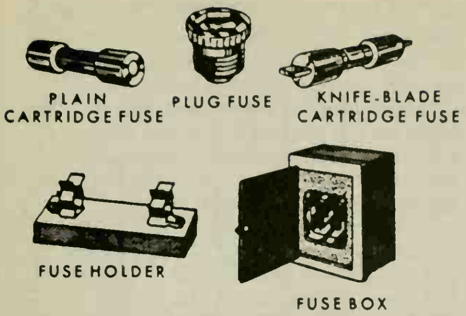
Circuit protective devices, as the name implies, all have a common purpose: to protect electrical units and the wires in the circuits. Some are designed primarily to protect the wiring. These open the circuit to stop the current flow when the current becomes greater than the wires can safely carry. Other devices are designed to protect a unit in the circuit by stopping current flow to it when the unit becomes excessively warm.

FUSES

The simplest protective device is a fuse. All fuses are rated according to the amount of current that can be safely carried by the fuse element at a rated voltage. Usually, the current rating is in amperes, but some instrument fuses are rated in fractions of an ampere. When a fuse blows, it should be replaced with another of the same rated voltage and current capacity, including the same current-versus-time characteristic.

The most important fuse characteristic is its current-versus-time, or "blowing," ability. Three time ranges for tolerance of overloads can be broadly defined as fast, medium, and delayed. Fast may range from five microseconds through a half second; medium, a half second to five seconds; delayed, five to twenty-five seconds.

Normally, when the circuit is overloaded, or a fault develops, the fuse element melts and opens the circuit that it is protecting. However, all fuse openings are not the result of current overload or circuit faults. Abnormal production of heat, aging of the fuse element, poor contact due to loose connections, oxides or corrosion forming within the fuse socket or holder, and high temperatures in the surrounding atmosphere will alter the heating conditions and the time required for the element to melt.



Typical fuses and fuse box

Plug Fuses

The plug fuse is constructed so that it can be screwed into a socket mounted on the control panel or distribution center. The fuse link is enclosed in an insulated housing of porcelain or glass and is visible through a window of mica or glass. An open element can be located by visual examination. When a fuse is defective, discard it and install a new fuse in its place. The plug fuse is used primarily to protect low-voltage, low-current circuits. The operating ratings range from 0.5 to 30 amperes and up to 150 volts.

Cartridge Fuses

In operation, the cartridge fuse is exactly the same as the plug fuse. In construction, the fuse link is enclosed in a tube of insulating material with metal ferrules at each end (for contact with the fuse holder). The dimensions of cartridge fuses vary with the current and voltage ratings.

Delayed-Action Fuses

Some equipment, such as an electric motor, requires more current for starts than for normal running. Thus, a fuse with a fast or medium rating might blow during the startup period when high current is required. Delayed-action fuses are used to handle these situations.

In one type of delayed-action fuse, the heater element is connected in parallel with the fuse element to achieve delayed action. During normal operation, the heat developed in the fuse link is not great enough to melt the link. The melting, or opening, of the fuse link depends on the transfer of heat to the link from the heater. Therefore, more time is needed to melt the link than would be required if the link were directly heated.

Because the heater and fuse element are in parallel, the opening of the fuse element will cause the total circuit current to flow through the heater. The high current will burn out the heater and open the circuit.

In another type of delayed-action fuse, the fuse element and heater are connected in series. Current above that of the rated value for a short time will have no effect on the fuse or heater element. However, prolonged overloads cause the heater to become hot enough to melt the junction between the elements and open the circuit.

Blown-Fuse Indicators

It is not always possible to detect a blown fuse by a visual examination. Hence, fuses are often equipped with a device that will provide a visual indication so that a blown fuse can be readily detected. These devices consist of spring-loaded and neon lamp blown-fuse indicators.

When the link of the spring-loaded indicator opens, it releases a spring that is held under tension. This action exposes an indicator, which makes the visual location of the blown fuse possible. The neon lamp indicator is designed to be mounted on the fuse. When the link opens, a neon lamp glows to show a blown fuse. When no indicator is used, you must test the fuse continuity with an ohmmeter or a voltmeter.

Most fuse panels and switchboards are enclosed panels. The term *dead front* means that all fuses and connections are enclosed in a metal cabinet when the cover is closed. This construction reduces the possibility of equipment damage and personal danger. Modern switchboards are of the dead-front type.

Complete enclosure of the equipment, however, makes it less accessible for testing. Therefore, most fuses used on dead-front switchboards have indicators that show when a fuse

is blown. The fuse holder consists of a molded phenolic base, plug, and cap with a built-in indicator lamp (blown-fuse indicator). The lamp is usually a small neon bulb, which normally is shunted by the fuse element. When the fuse opens, the shunt is removed, causing an increase in the voltage across the neon lamp. The lamp then glows.

TROUBLESHOOTING FUSED CIRCUITS

An electrical system may consist of a comparatively small number of circuits, or in larger systems the installation may be equal to that of a fairly large city. Regardless of size, an electrical system consists of a source of power (generator or batteries) and a means of delivering this power from the source to the various loads (lights, motors, and other equipment).

From the main power supply, the total electrical load is divided into several feeder circuits, and each feeder circuit is further divided into several branch circuits. Each final branch circuit is fused to safely carry only its own load, and each feeder is safely fused to carry the total current of its several branches. This precaution reduces the possibility of one circuit failure interrupting the power for the entire system. The feeder distribution boxes and the branch distribution boxes contain fuses to protect the various circuits.

The distribution wiring diagram showing the connections that might be used in a lighting system is illustrated. An installation might have several feeder distribution boxes, each supplying six or more branch circuits through branch distribution boxes.

Fuses F_1, F_2, and F_3 protect the main feeder supply from heavy surges such as short circuits or overloads on the feeder cable. Fuses A-A_1 and B-B_1 protect branch No. 1. If trouble develops and work is to be done on branch No. 1, switch S_1 can be opened to isolate this branch. Branches 2 and 3 are protected and isolated in the same manner by their respective fuses and switches.

Branch Circuit Tests

Usually, receptacles for portable equipment and fans are on branch circuits separate from lighting branch circuits. Test procedures are the same for any branch circuit. Therefore, a description will be given of the steps necessary to locate the defective circuit and follow through on that circuit and find the trouble.

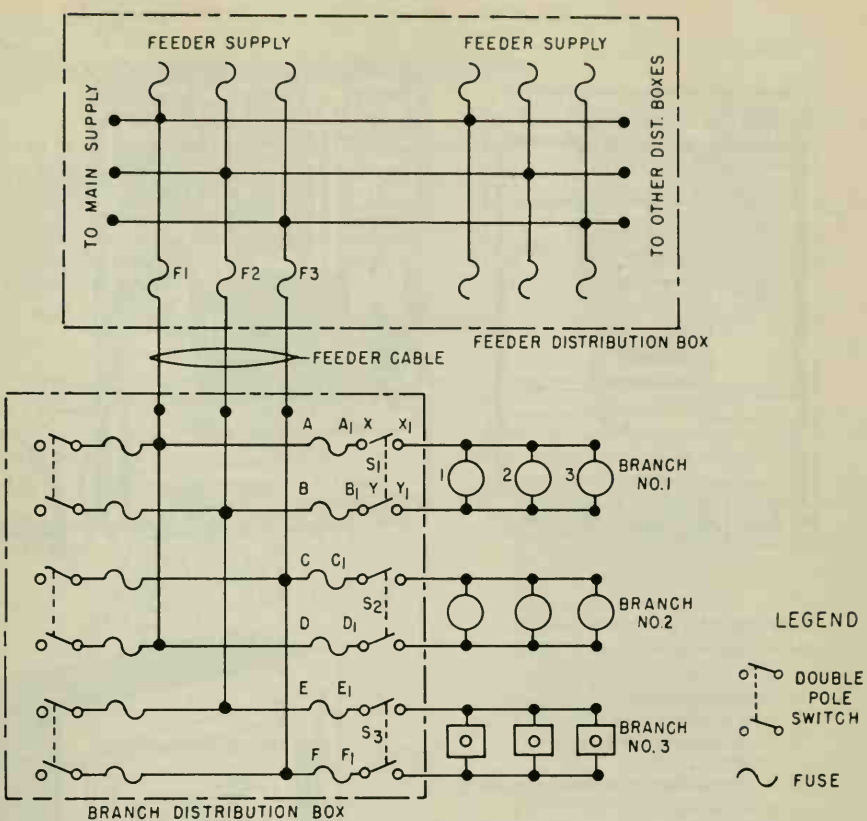
Assume that, for some reason, several of the lights are not working in a certain section. Because several lights are out, it is reasonable to assume that the voltage supply has been interrupted on one of the branch circuits.

To verify this assumption, first locate the distribution box feeding the inoperative circuit. Then make sure that the inoperative circuit is not being supplied with voltage. Unless the circuits are identified in the distribution box, you will have to measure the voltage at the various circuit terminations. For the following procedures, use the circuits shown in the three-phase wiring diagram as an example.

To pin down the trouble, connect the voltage tester to the load side of each pair of fuses in the branch distribution box. No voltage between these terminals indicates a blown fuse or a failure in the supply to the distribution box. To find the defective fuse, make certain S_1 is closed, then connect the voltage tester across A-A_1 and next across B-B_1. The full-phase voltage will appear across an open fuse, provided circuit continuity exists across the branch circuit. However, if there is an open circuit at some other point in the branch circuit, this test is not conclusive. If the load side of a pair of fuses does not have the full-phase voltage across its terminals, place the tester leads on the supply side of the fuses. The full-phase voltage should be present. If the full-phase voltage is not present on the supply side of the fuses, the trouble is in the supply circuit from the feeder distribution box.

Assume that you are testing at terminals A-B and that normal voltage is present. Move the test lead from A to A_1. Normal voltage between A_1 and B indicates that fuse A-A_1 is in good condition. To test fuse B-B_1, place the tester leads on A and B, and then move the lead from B to B_1. No voltage between these terminals indicates that fuse B-B_1 is open. Full-phase voltage between A and B_1 indicates that the fuse is good.

This method of locating blown fuses is preferred to the method in which the voltage



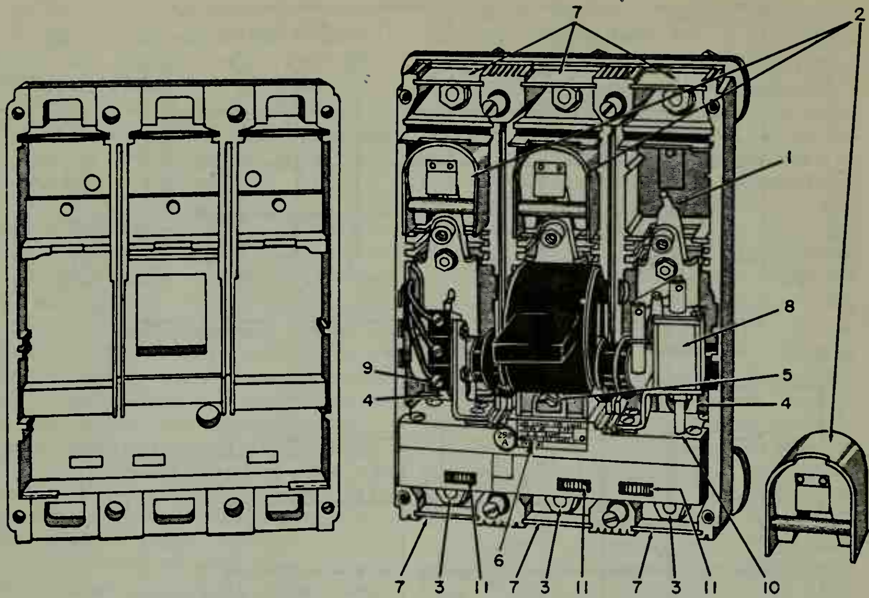
Three-phase distribution wiring diagram

tester leads are connected across the suspected fuse terminals, because the latter may give a false indication if there is an open circuit at any point between either fuse and the load in the branch circuit.

CIRCUIT BREAKERS

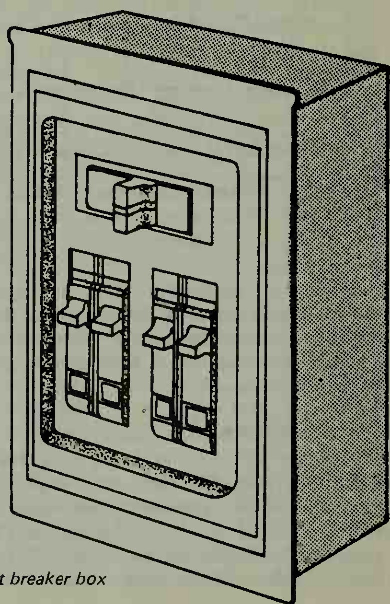
A circuit breaker is designed to break the circuit and stop the current flow when the current exceeds a predetermined value. It is commonly used in place of a fuse and may sometimes eliminate the need for a switch. A circuit breaker differs from a fuse in that it "trips" to break the circuit and it may be reset, while the fuse element melts and the fuse must be replaced.

Several types of circuit breakers are commonly used. One is a magnetic type. When excessive current flows in the circuit, it makes an electromagnet strong enough to move a small armature that trips the breaker. Another type is the thermal overload switch or breaker. This consists of a bimetallic strip that will overheat from excessive current, bend away from a catch on the switch lever, and permit the switch to trip open.

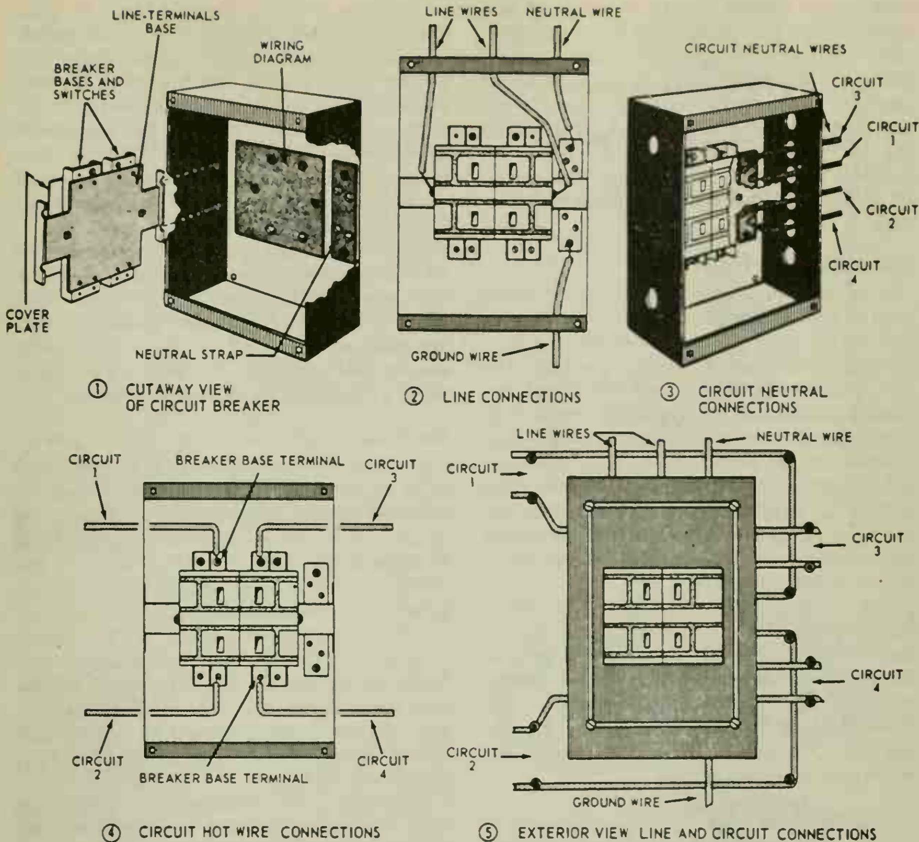


Circuit breaker with the cover and one arc suppressor removed

1. Stationary contact.
2. Arc suppressors.
3. Terminal stud nuts and washers.
4. Trip unit line terminal screw-outer poles.
5. Trip unit line terminal screw-center pole.
6. Trip unit nameplate.
7. Terminal barriers.
8. Shunt trip.
9. Auxiliary switch.
10. Hole for shunt trip undervoltage release plunger.
11. Instantaneous trip adjusting wheels.



Typical circuit breaker box



Typical circuit breaker wiring

Some circuit breakers must be reset by hand; others reset themselves automatically. If the overload condition still exists when the circuit breaker is reset, the circuit breaker will trip again to prevent damage to the circuit.

One common type of circuit breaker is designed for front or rear connections, as required. It can be mounted so that it can be removed from the front with the circuit breaker cover in place. The voltage ratings of this breaker are 500 volts AC, 60 Hertz, or 250 volts DC with a maximum current capacity of 250 amperes. Trip units for this breaker are available with current ratings of 125, 150, 175, 225, and 250 amperes.

The trip unit houses the electrical tripping mechanisms, the thermal element for tripping the circuit breaker on overload conditions, and the instantaneous trip for tripping in short-circuit conditions. The automatic trip devices of this circuit breaker are "trip free" of the operating handle; that is, the circuit breaker cannot be held closed by the operating handle if an overload exists. When the circuit

breaker has tripped due to an overload or a short circuit, the handle rests in a center position. To reclose it after automatic tripping, you must move the handle to the extreme off position. This action resets the latch in the trip unit. Then the handle must be moved to the on position. Metal locking devices are available that can be attached to the handles of circuit breakers to prevent accidental tripping.

THERMAL PROTECTORS

A thermal protector or switch is a device used to protect a motor. It is designed to open the circuit automatically whenever the temperature of the motor becomes too high. The switch has two positions, open and closed. The most common use for a thermal switch is to keep a motor from overheating. If some malfunction in the motor causes it to overheat, the thermal switch will break the circuit intermittently. If the trouble is a locked rotor, the intermittent opening and closing of the circuit may release the rotor and allow the motor to resume normal operation.

The thermal switch contains a bimetallic disk, or strip, which bends and opens the circuit when it is heated. This happens because one of the metals expands more than the other when it is subjected to elevated temperatures. When the strip or disk cools, the metals contract and the strip returns to its original position and closes the circuit.

OVERLOAD DEVICE

A prolonged overload can damage an electrical system beyond repair due to the resulting heat and flame. Therefore, it is expedient to use a device that can detect an overload before damage occurs and either warns the operator of the hazardous condition or automatically turns off the power. Relays have been designed that are capable of accomplishing these protective functions.

CONTROL DEVICES

Control devices are electrical accessories that govern (in some predetermined way) the power delivered to any electrical load. In its simplest form, the control applies voltage to, or removes it from, a single load. In more complex control systems, the initial switch may set into action other control devices that govern motor speeds, servomechanisms, temperatures, and numerous pieces of equipment. In fact, all electrical systems and equipment are controlled in some manner by one or more controls. A controller is a device or group of devices that governs, in some predetermined manner, the device to which it is connected.

In large electrical systems, it is necessary to have a variety of controls for operation of the equipment. These controls range from simple push buttons to heavy-duty contactors that are designed to control the operation of large motors. The push button is manually operated while a contactor is electrically operated.

Switches

A switch may be described as a device used in an electrical circuit for making, breaking, or changing connections under conditions for which the switch is rated. Switches are rated in amperes and volts. The rating refers to the maximum voltage and current of the circuit in which the switch is to be used. Because the switch is connected in series, all the circuit current will pass through it. Because the switch opens the circuit, the applied voltage will appear across the switch in the open circuit position. Switch contacts should be opened and closed quickly to minimize arcing; therefore, switches normally utiliza a snap action.

Many types and classifications of switches have been developed. They are commonly designated by the number of poles, throws, and positions they have. The number of poles indicates the number of terminals at which current can enter the switch. The throw of a switch signifies the number of circuits each blade or contactor can complete through the switch. The number of positions indicates the number of places at which the operating device (toggle, plunger, etc.) will come to rest.

An example of the switch position designation is a toggle switch that comes to rest at either of two positions, opening the circuit in one position and completing it in another. This is called a two-position switch. A toggle switch that is spring loaded to the off position

and must be held in the on position to complete the circuit is called a momentary contact two-position switch. If the toggle switch will come to rest at any of three positions, it is called a three-position switch.

Another means of classifying switches is the method of actuation; that is, toggle, push-button, sensitive, and rotary types. They can be further classified by a description of switch action, such as on-off, momentary on-off, on-momentary-off, and so forth. Momentary contact switches hold a circuit closed or open only as long as the operator deflects the actuating control.

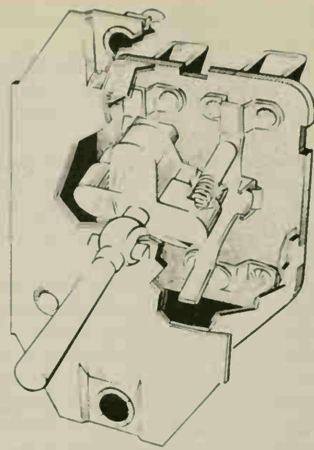
Manually operated switches: One of the most common types of switches is the toggle. Toggle switches have their moving parts enclosed. Double-pole, double-throw, and on-off-on toggle switches have many uses, especially for applying power to various circuits. Their levers often have luminous tips so that they are visible in the dark.

Push-button switches have one or more stationary contacts and one or more movable contacts. The movable contacts are attached to the push button by an insulator. The switch is a momentary contact switch that is usually spring loaded. The type is particularly useful with indicator light checks and in circuit resetting.

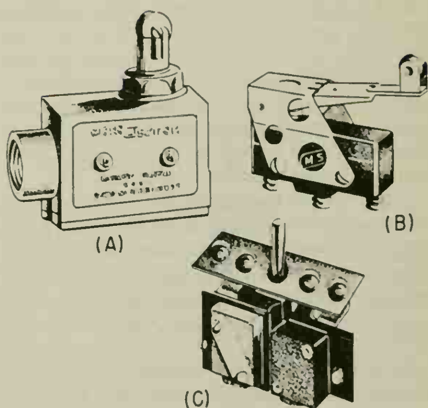
A rotary selector switch may perform the functions of a number of switches. As the knob of a rotary selector switch is rotated, it opens one circuit and closes another. Some rotary switches have several layers of wafers. By adding wafers, you can make the switch operate as a large number of switches. Ignition switches and voltmeter selector switches are typical examples of this type.

Mechanically operated switches: Mechanically operated switches are used in many applications because of their small size, light weight, and dependability. These switches will open or close a circuit with a very small movement of the tripping device ($^1/_{16}$ inch or less). They are usually push buttons, and they depend on one or more springs for their snap action.

Pressure-operated switches usually have Bourdon tubes, siphons, or diaphragms against which fluids or air act to actuate the switch.



Toggle switch



Snap-action switching units

Some uses of pressure switches are in fuel, oil, and hydraulic pressure signals and in electric heaters.

Thermal switches usually incorporate a bimetallic sheet that bends or snaps at a desired temperature to actuate the switch. They are used extensively as circuit breakers, and they also find application in controlling the igniter

circuit on heaters and in operating signal lights at critical temperatures.

Maintenance of switches: While switches are relatively simple to check, they sometimes offer difficulty in maintenance because they are located in inaccessible places. After a visual inspection of the connections and the switch, a continuity test will indicate any malfunctions. When a switch mechanism is found to be defective, it is normally not repairable and should be replaced.

When enclosed switches are used, failure to seal properly around cable openings may cause difficulty. Altitude changes permit "breathing" of moist air into enclosures with improperly sealed cable openings, and the moisture in the air may condense in the switch enclosure. The condensation can short across the switch terminals and can corrode the switch actuators so that they become inoperative. This difficulty can be corrected by careful sealing of openings or by using hermetically sealed switches. Hermetically sealed switches will also prevent dust and dirt from reaching the contacts and will thereby reduce the possibility of high resistance and open circuits.

Some switches are damaged during installation, particularly those with plastic housings. Proper care in installing or replacing plastic enclosed switches will eliminate this.

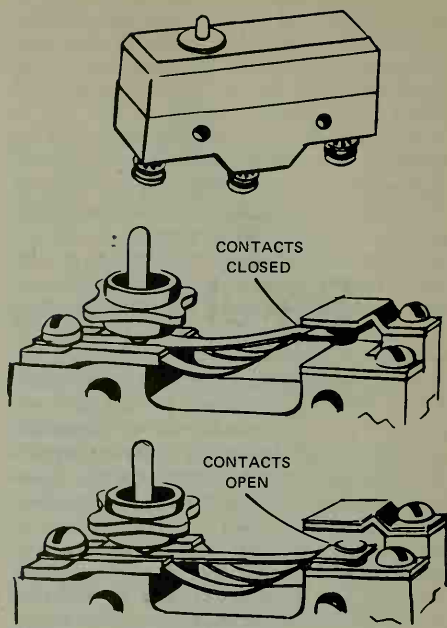
Some switch assemblies are equipped with adjustments that enable them to operate at a preset time or pressure. Caution should be exercised in making these adjustments; if they are not accurate, damage can result.

Relays

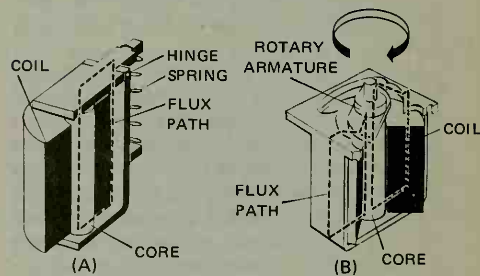
Relays are electrically operated switches that are classified according to their use as control relays, power relays, or sensing relays. The power relays are the workhorses of a large electrical system. As such, they control the heavy power circuits.

The function of a control relay is to use a relatively small amount of electric power either to signal or to control a large amount of power. Where multiple relays are used, several circuits can be controlled simultaneously.

The use of relays saves space and weight by permitting the use of small switches at remote control stations. These switches permit an operator to control large amounts of current at other locations, and the heavy power cables need to be run only to the point of use (only lightweight control wires are connected to the control switches). Safety is also an important factor in using relays, since high power circuits can be switched remotely without danger to the operator.



Micro switch



Basic types of relays

7
Safety

Every person who works with electrical equipment should be constantly alert to the hazards to which he may be exposed and should be capable of rendering first aid. The installation, operation, and maintenance of electrical equipment requires adherence to a stern safety code. Carelessness can result in serious injury or even death due to electric shock, burns, falls, and so forth. After an accident has occurred, investigation almost invariably shows that it could have been prevented if safety precautions had been taken.

BASIC SAFETY PRECAUTIONS

Take time to be safe when you are working on electrical circuits and equipment. Carefully study the schematics and wiring diagrams of the entire system. Be sure to note which circuits must be deenergized if you do not cut off the main power supply. Do not work on any equipment with the power on unless it is necessary.

Always be aware of the nearness of high voltage lines or circuits. Use rubber gloves where moisture is present or if your hands perspire heavily.

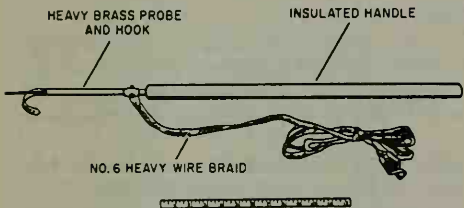
Keep your clothing, hands, and feet dry if at all possible. When it is necessary to work in wet or damp locations, use a dry platform or wooden stool to sit or stand on, and place a rubber mat or other nonconductive material on top of the wood. Use insulated tools and molded insulated flashlights when you must work on exposed parts.

Do not wear loose or flapping clothing. Be sure that your clothing does not have metal buttons, exposed zippers, or other metal trim. Remove all rings, watches, bracelets, and similar metal items.

Use one hand when turning switches on or off. Keep the doors to switch and fuse boxes closed except when working inside them or replacing fuses. Use a fuse puller to remove cartridge fuses after first making certain that the power to the circuit is cut off.

Use a shorting stick to discharge all high voltage charges. Before you touch a capacitor or any part of a circuit that is known or likely to be connected to a capacitor (whether the circuit is deenergized or disconnected entirely), you should short-circuit the terminals to make sure that the capacitor is completely discharged.

Be smart enough to recognize when a job is too dangerous to do yourself.



A shorting stick should be used to discharge all high-voltage charges.

Make certain that the equipment is properly grounded. Ground all test equipment to the equipment you plan to test. Turn off the power before connecting alligator clips to any circuit.

PRECAUTIONS WHEN USING ELECTRIC TOOLS

When using a portable power drill, grasp it firmly to prevent it from bucking or breaking loose and causing injury to yourself or damage to the tool. Use only straight, undamaged, and properly sharpened drills. Tighten the drill bit securely in the chuck, using the key that is provided; never try to tighten the drill with wrenches or pliers. It is important that the drill bit be set straight and true in the chuck.

All portable power tools should be carefully inspected before being used to see that they are clean, well-oiled, and in a proper state of repair. The switches should operate normally, and the cords should be clean and free of defects in insulation. The cases of all electrically driven tools should be grounded. Portable electric tools that give off sparks should not be used in any place where flammable vapors, gases, liquids or explosives are present.

Be sure that power cords do not come in contact with sharp objects. The cords should not be allowed to kink, nor should they be left where they might be run over or walked on. They should not be allowed to come in contact with oil, grease, hot surfaces, or chemicals. When the cords are damaged, they should be replaced instead of being patched with tape. When you unplug power tools from receptacles, grasp and pull the plug, not the cord.

In selecting a screwdriver for electrical work, be sure that it has a nonconducting handle. Do not use the screwdriver as a substitute for a punch or a chisel, and take care to select one of the proper size to fit the screw.

When using a fuse puller, make certain that it is the proper type and size for the particular fuse being pulled.

The soldering iron is a fire hazard and a potential source of burns. Always assume that a soldering iron is hot; never rest the iron anywhere but on a metal surface or rack provided for that purpose. Keep the iron holder in the open to minimize the danger of fire from heat buildup. Do not shake the iron to dispose of excess solder because a drop of hot solder may strike someone or strike the equipment and cause a short circuit. Hold small soldering jobs with pliers or clamps.

When cleaning a soldering iron, place the cleaning rag on a suitable surface and wipe the iron across it. Do not hold the rag in the hand. Disconnect the iron when leaving the work, even for a short time. The delay may be longer than planned.

BATTERY SAFETY PRECAUTIONS

The principal hazard in connection with batteries is the danger of acid burns in refilling or handling them. Acid burns can be prevented by the proper use of eyeshields, rubber gloves, rubber aprons, and rubber boots with nonslip soles. The rubber boots and apron need be worn only when batteries are being refilled. It is a good practice, however, to wear the eyeshield whenever you work around batteries to prevent the possibility of acid burns of the eyes. Wood slat floorboards, if kept in good condition, are helpful in preventing slips and falls as well as electric shock from the high-voltage side of charging equipment.

Another hazard in working with batteries is the danger of explosion due to the ignition of hydrogen gas given off during the battery charging operation. This is especially true where the accelerated charging method is used. Open flames or smoking should not be allowed in the area, and the charging rate should be held at a point that will prevent the rapid liberation of hydrogen gas. Manufacturers' recommendations concerning the charging rates for batteries should be closely followed and a room ventilation system should be used during charging.

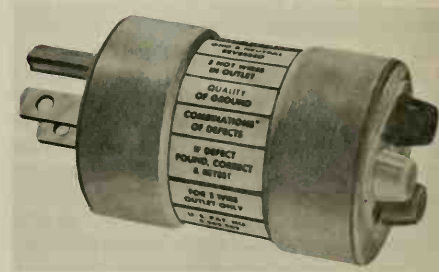
Particular care should be taken to prevent short circuits while batteries are being charged, tested, or handled. Hydrogen gas, which is accumulated while charging, is highly explosive; a spark from a shorted circuit could easily ignite the gas, causing serious personal injury and damage to equipment.

Extreme caution should be exercised in installing and removing batteries. Batteries are heavy for their size and are somewhat awkward to handle. These characteristics dictate the need to use proper safety precautions.

GROUNDING OF EQUIPMENT

A poor safety ground, or one that is wired incorrectly, is more dangerous than no ground at all. The poor ground is dangerous because it does not offer full protection and the user is lulled into a false sense of security. The incorrectly wired ground is a hazard because one of the line wires and the safety ground are transposed, making the housing of the tool

A ground-fault circuit interrupter can prevent serious injury or even death from electric shock.



Circle F's CircTest® instantly checks wall receptacles to be sure they are wired correctly.

"hot" the instant the plug is connected; that is, the tool housing becomes a conductor. Thus, the unwary user is trapped, unless by pure chance the safety ground is connected to the grounded side of the line on a single-phase grounded system or unless no grounds are present on an ungrounded system. In this instance the user again goes blithely along

using the tool until he encounters a receptacle that has its wires transposed or until a ground appears in the system.

Because there is no absolutely foolproof method of ensuring that all tools are safely grounded (and because of the tendency of the average person to ignore the use of the grounding wire), the old method of using a separate external grounding wire has been discontinued. Instead, a three-wire, standard, color-coded cord with a polarized plug and a ground pin is strongly recommended. In this manner, the safety ground is made a part of the connecting cord and plug. Since the polarized plug can be connected only to a mating receptacle, the user has no choice but to use the safety ground.

All new tools, properly connected, use the green wire as the safety ground. This wire is attached to the metal case of the tool at one end and to the polarized grounding pin in the connector at the other end. It normally carries no current, but is used only when the tool insulation fails, in which case it short-circuits the electricity around the user to ground and protects him from shock. The green lead must never be mixed with the black or white leads which are the true current-carrying conductors.

Check the resistance of the grounding system with a low-reading ohmmeter to be certain that the grounding is adequate (less than 1 ohm is acceptable). If the resistance measures more than 1 ohm, use a separate ground strap.

Some old installations are not equipped with receptacles that will accept the grounding plug. In this case, use one of the following methods:

1. Use an adapter fitting.
2. Use the old plug and bring the green ground wire out separately.
3. Connect an independent safety ground line.

When using the adapter, be sure to connect the ground lead extension to a good ground. (Do not use the center screw that holds the cover plate on the receptacle.) Where the separate safety ground leads are externally connected to a ground, be certain to first connect the ground and then plug in the tool. Likewise, when disconnecting the tool, first remove the line plug and then disconnect the safety ground. The safety ground is always connected first and removed last.

PREVENTING ELECTRICAL FIRES

General cleanliness of your work area and of electrical apparatus is essential for the prevention of electrical fires. Oil, grease, and carbon dust can be ignited by electrical arcing. Therefore, electrical and electronic equipment should be kept absolutely clean and free of all such deposits.

Wiping rags and other flammable waste material must always be placed in tightly closed metal containers, which must be emptied at the end of the day's work.

FIGHTING ELECTRICAL FIRES

In case of electrical fires, the following steps should be taken:

1. Deenergize the circuit.
2. Call the Fire Department.
3. Control or extinguish the fire, using the correct type of fire extinguisher.

For combating electrical fires, use a CO_2 (carbon dioxide) fire extinguisher and direct it toward the base of the flame. Carbon tetrachloride should never be used for fire fighting since it changes to phosgene (a poisonous gas) upon contact with hot metal, and even in open air this gas is a hazard. Applying water to electrical fires is extremely dangerous, and foam fire extinguishers should not be used since the foam is electrically conductive.

When the inner layers of cable insulation or insulation covered by armor are burning, the only positive method of preventing the fire from running the length of the cable is to cut the cable and separate the two ends. All power to the cable should be shut off if possible, and the cable should be cut with a wood-handled ax or an insulated cable cutter. Keep away from the ends after they have been cut if the power was not shut off.

When selenium rectifiers burn out, fumes of selenium dioxide are liberated, causing an overpowering stench. The fumes are poisonous

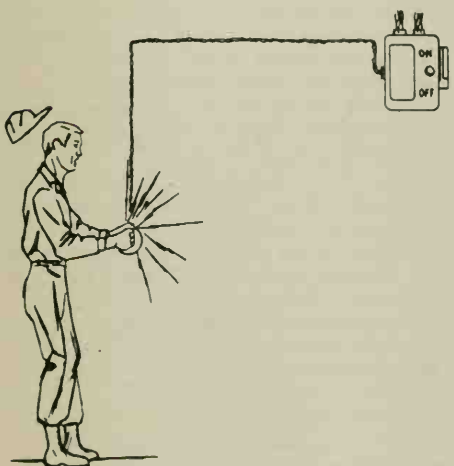
and should not be inhaled. If a rectifier burns out, deenergize the equipment immediately and ventilate the area. Allow the damaged rectifier to cool before attempting any repairs. If possible, move the equipment containing it out of doors. Do not touch or handle the defective rectifier while it is hot. You might receive a skin burn, through which some of the selenium compound could be absorbed.

Fires involving wood, paper, cloth, or explosives should be fought with water. Water works well on them. Therefore, take advantage of its low cost, availability, and safety in handling.

A steady stream of water does not work in extinguishing fires involving substances like oil, gasoline, kerosene, or paint because these substances will float on top of the water and keep right on burning. Also, a stream of water will scatter the burning liquid and spread the fire. For this reason, foam or mist must be used in fighting such fires.

EFFECTS OF ELECTRICITY ON THE BODY

The amount of current that may pass through the body without danger depends on the individual and the voltage, type, path, and length of contact time. Body resistance varies from 1,000 to 500,000 ohms for unbroken, dry skin. Resistance is lowered by moisture and high voltage, and it is highest with dry skin and low voltage. Breaks, cuts, or burns may lower body resistance. A current of 1 milliampere can be felt and will cause an avoidance reaction. A milliampere is a very small amount of current—$^1/_{1000}$ of an ampere. Current as low as 5 milliamperes can be dangerous. If the palm of the hand makes contact with the conductor, a current of about 12 milliamperes will tend to cause the hand muscles to contract, freezing the body to the conductor. Such a shock may or may not cause serious damage, depending on the contact time and your physical condition, particularly the condition of your heart. A current of only 25 milliamperes has been known to be fatal; 100 milliamperes is likely to be fatal.



"Hot" circuits can kill.

Five times more direct current than alternating current is needed to freeze the same body to a conductor. Also, 60-hertz (cycles per second) alternating current is about the most dangerous frequency. This is the frequency normally used in residential, commercial, and industrial power.

The damage from shock is also proportional to the number of vital organs that the current transverses. The heart is especially sensitive to electric current.

Currents between 100 and 200 milliamperes are lethal. Ventricular fibrillation of the heart occurs when the current through the body approaches 100 milliamperes. Ventricular fibrillation is uncoordinated action of the muscles of the ventricles. This in turn causes failure of the heart's pumping action. Fibrillation will usually continue until some force is used to restore coordination to the heart muscles.

Severe burns and unconsciousness are also produced by currents of 200 milliamperes or more. These currents usually do not cause death if a victim is given immediate attention. A victim usually will respond to artificial respiration because 200 milliamperes of current cramp the heart muscles, arresting the heartbeat but preventing the heart from going into ventricular fibrillation.

When a person is rendered unconscious by a current passing through the body, it is impossible to tell how much current caused the unconsciousness. Artificial respiration must be applied immediately if breathing has stopped.

ELECTRIC SHOCK

Electric shock is a jarring sensation resulting from contact with electric circuits or from the effects of lightning. The victim usually feels that he has received a sudden blow. If the voltage and resulting current is sufficiently high, the victim may become unconscious. Severe burns may appear on the skin at the place of contact, and muscular spasm may occur, causing the victim to clasp the apparatus or wire that caused the shock and be unable to release it.

The following procedures are recommended for rescue and care of shock victims:

1. Remove the victim from electrical contact at once, but do not endanger yourself. Throw the switch controlling the circuit if it is nearby; cut the cable or wires to the apparatus, using an ax with a wood handle and taking care to protect your eyes from the flash when the wires are severed; use a dry stick, rope, belt, coat, blanket, or any other nonconductor of electricity to drag or push the victim to safety.
2. Determine whether the victim is breathing. Keep him lying down in a comfortable position, and loosen the clothing around his neck, chest, and abdomen so that he can breathe freely. Protect him from exposure to cold, and watch him carefully.
3. Keep him from moving about. After an electric shock, the heart is very weak, and any sudden effort or activity on the part of the victim may result in heart failure.
4. Do not give stimulants or opiates. Send for a doctor at once, and do not leave the victim until he has adequate medical care.
5. If the victim is not breathing, it will be necessary to apply artificial respiration without delay, even though he may appear to be lifeless. Do not stop artificial respiration until the victim begins to breathe again or until a doctor declares that the victim is beyond help.

8
Simple Repairs

This chapter is devoted to the kind of simple electrical repairs that anyone can do. These involve common problems such as replacing a broken plug, a malfunctioning wall switch, a damaged wall receptacle, or a defective bulb socket and fixing a doorbell that refuses to ring. Also included is information on three-way switches and dimmer switches.

Many people are afraid to tackle simple electrical repairs because they don't know how to proceed or because they are afraid of electric shock. The most important thing to remember is to pull the circuit breaker or remove the fuse that delivers electric current to the area. With the exception of some doorbell repair work, never work on an open circuit. Once power to the circuit is shut off, you need not fear electric shock.

GENERAL RULES AND PROCEDURES

The repairs and replacements discussed in this chapter require very little in the way of equipment. In most cases, a screwdriver and the replacement parts are all that are needed. However, unless you are working in daylight, you may also need a flashlight. Remember that when you shut off power to the electric circuit, you are removing your light source.

A careful workman leaves nothing to chance. If you have removed a fuse, put it in a safe place where you can find it easily, or better yet, put it in your pocket so that no one will accidentally replace it while you are still working. If you have thrown a circuit breaker, make sure that everyone in the house is aware that you are working so that they won't try to use the circuit before you are ready. When this isn't possible, leave a note on the box indicating that you are working.

To simplify your work, use a box or a dry bowl to store screws and other parts. As you remove the parts, place them in the box or bowl so that they don't roll away. Never put screws in your mouth. Moisture on the screw can cause a short circuit when the power is turned on again.

With many of these repairs, wires must be pulled out of the outlet or receptacle box. Never pull too hard. When you feel resistance from the wires, stop pulling. You will find that you don't need to pull the wires very far out of the box to work on them.

In replacing parts, it is helpful to have the correct parts on hand before you begin work. However, this isn't always possible. When you suddenly find that you have the wrong parts or that you need additional parts, take certain precautions before you leave the work area, particularly in situations where children have access to exposed wires and parts.

Tape the ends of all exposed wires with electrical tape and replace them in the box. Then, remount the faceplate. It is also important to put the box or bowl containing all of the other parts in a place where children cannot reach it.

When you have finished your work, check to see that no extra screws are left over. Extra screws usually mean that you have left out screws that belong inside the box.

Finally, replace the fuse or throw the circuit breaker to restore power.

REPLACING A PLUG

Damaged or defective plugs are dangerous. They can cause shocks and start fires. A plug that is worn, cracked, or broken, or that is warm to the touch when carrying a current should be replaced at once.

Before you begin work, remove the plug from the wall receptacle. Examine it closely so that you will know what kind of replacement to purchase.

Cut the cord an inch or so away from the plug. Split the cord for an inch or two and carefully remove the insulation from the two wires. Be careful not to cut or nick the wires. If you do so, cut and remove wire to a point beyond the damaged spot. Next, insert the wires into the new plug and wind each wire around its terminal. The wire should be wound clockwise so that when you turn the screw, it will tighten and not loosen the wire. Tighten the screws and insert the insulating material over the exposed part of the plug. To secure the plug more firmly on the cord, tie an Underwriters' knot in the wires before winding them around the terminals.

Some newer plugs are made of plastic and can be clamped directly onto the wires. This type is simpler to install but is not as sturdy and should not be used for heavy appliances.

REPLACING A WALL SWITCH

Sometimes it is obvious that a wall switch needs replacing. At other times, the malfunction may manifest itself by causing the lights to flicker or burn with more or less intensity.

To replace a defective wall switch, first break the electrical circuit. Never work on an open circuit. Next, unscrew the two screws that hold the switch faceplate. If the faceplate has been painted, it may stick to the wall. In removing it, be careful not to chip the paint on the faceplate or on the adjacent wall area.

When the switch is exposed, unscrew the screws that hold it in place. Pull the switch and the attached wires out of the box. Loosen the two screws that attach the wires to the switch and then remove the switch.

The new switch is attached in the same way; simply reverse the process. When you attach the wires to the new switch, be sure that the wires are wound in a clockwise direction so that tightening the screws will tighten the wires and not loosen them. After attaching the wires, carefully put them and the new switch back into the box and insert the holding screws in the switch "ears." Replace the switch faceplate and its screws.

REPLACING A WALL RECEPTACLE

A receptacle that is not functioning well or that has been damaged should be replaced. Before doing any work on a wall receptacle, break the circuit that delivers power to the receptacle.

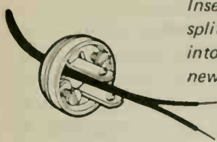
Remove the screw in the center of the receptacle and remove the faceplate. If the plate has been painted, be careful in removing it; otherwise, you may chip or crack the paint on it or the area surrounding it.

Next, unscrew the two mounting screws that hold the unit in position, and pull it out of the receptacle box. Loosen the screws on the unit (called set, or terminal, screws) to release the wires.

You will notice that one wire is white and one wire is black. The black wire is the "hot" wire; the white is the "neutral" wire. In replacing the receptacle, wrap the black wire around the brass terminal; wrap the white wire around the silver terminal. When you

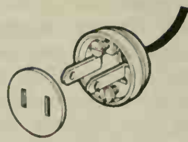
REPLACING A PLUG

ONE WAY



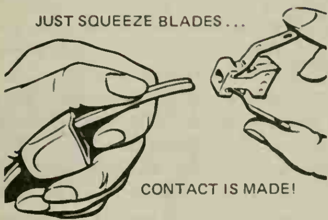
Inserting the split wire into the new plug

Winding each wire around its terminal



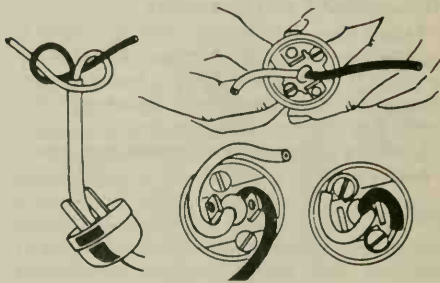
Inserting insulating material to cover the exposed wires and terminals

A QUICK WAY



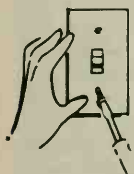
New plastic plugs make replacing worn plugs a snap.

MAKING UNDERWRITERS' KNOT

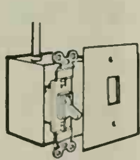


The Underwriters' knot

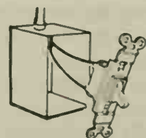
REPLACING A WALL SWITCH



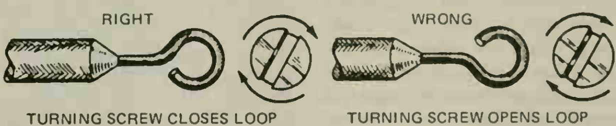
The first step in replacing a wall switch is to remove the faceplate.



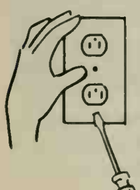
With the faceplate off, remove the screws holding the switch.



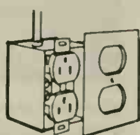
The switch and wires are gently pulled from the box.



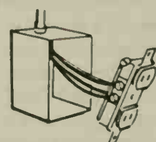
REPLACING A WALL RECEPTACLE



Remove the center screw that holds the faceplate in place.



Remove the mounting screws to free the unit from the box.



Gently pull the receptacle unit and the attached wires out of the box.

attach the wires, be sure that they are wrapped in a clockwise direction so that the screws will tighten the wires and not loosen them. If there is a green wire (a grounding wire), it should be wound around the green terminal in the same manner as the other wires.

Gently push the wires and the receptacle back into the box, replace the mounting screws and the receptacle plate, and install the center screw.

REPLACING A BULB SOCKET

When a lamp won't work, first be sure that the bulb is not at fault. Test the bulb by screwing it into a lamp that you know is functioning. If the bulb works in this lamp, it is likely that the bulb socket of the other lamp is defective and needs to be replaced.

Before you do any work on a lamp, unplug it to avoid electric shock. Check the contact spot. This is the spot in the well of the socket that makes contact with the bottom spot of the bulb. The contact spot may be dirty or slightly bent. After cleaning it and making any needed adjustments, put the bulb back in and plug in the lamp. If it still doesn't work, you will have to replace the socket.

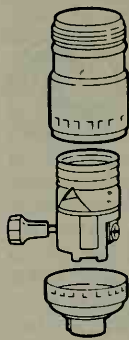
Again, first unplug the lamp and remove the bulb. To remove the old socket, look for the word *press* or *push* stamped into the metal near the switch. Pushing or pressing at that point will separate the two parts of the socket. If the metal offers resistance, wiggle it a little or try using a screwdriver to exert pressure.

Remove the cardboard or fiber liner of the socket. Loosen the terminal screws that hold the wires in place. Once the wires are free, you can remove the second part of the old socket. Installing the new socket is easy, just reverse the process.

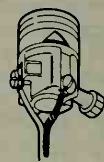
If the new socket cap doesn't fit as well as the old one did, try making an Underwriters' knot with the two wires. This knot should be placed under the socket cap.

Remember to wind the wire in a clockwise direction around the screws so that tightening the screws will tighten and not loosen the wire. Remember also to insert the cardboard or fiber lining in the new socket. This provides necessary insulation.

REPLACING A BULB SOCKET



The different parts of a lamp socket



After the terminal screws are loosened, the wires can be released.

You can replace the old socket in any lamp with a dimmer socket that has a switch to allow you to adjust the level of light.

FIXING A DOORBELL

Doorbells work on a relatively low voltage, usually between 15 and 24 volts, depending on whether there are one or two push buttons. A doorbell that uses only 15 volts can be worked on without the current being shut off. Doorbells that work on 24 volts should be disconnected because they will give you an electric shock, although not a serious one. If you don't know the exact voltage your doorbell uses, play it safe and break the circuit.

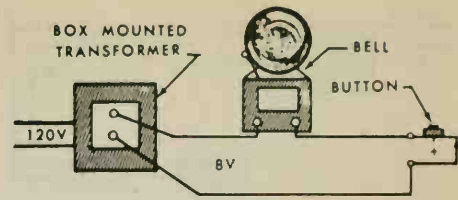
Most doorbell failure can be traced to the push button. This part of the system is constantly exposed to the elements, and over a period of time, it is likely to rust.

When your doorbell fails to ring, the first step is to remove the screws that hold the push button in place. (If you need to break the circuit, this should be done first.) Pull the push-button faceplate away from the wall and disconnect the two wires from the terminals by loosening the screws that hold them in place.

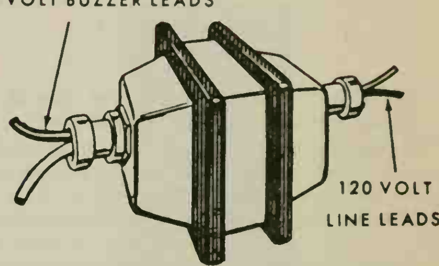
Bring the bare tips of the two wires together. (If the power has been shut off, you must restore power at this point. However, do not touch the bare wires with the power on.) If the doorbell sounds when the wires touch, the trouble is in the push button itself. This problem can easily be solved by replacing the push button. When you buy the new part, you may want to purchase a push button that has a small light inside it. The light draws current from the existing circuit and is useful in locating the doorbell at night.

If the bell doesn't work when the two wires touch (remember that the power must be on), try cleaning or scraping them so that a good contact is made. Be careful not to cut or nick the wires. If the bell still won't ring, the problem is not in the push button. Attach the wires to the push button and put it back in place.

The next place to look for a malfunction is the bell. All work on the bell should be done with the current off. After removing the cover, check to see that the wires are all in their proper places and that they are tightly held by the screws. Be sure that the contact is clean. If your bell box is located in or near the kitchen, the problem may be an accumulation of grease.



Common doorbell wiring



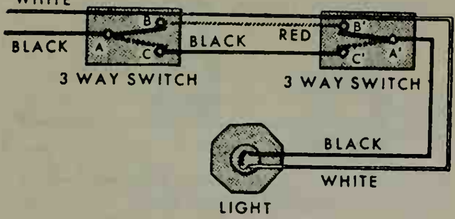
The transformer reduces the regular house current to a lower voltage so that it can be used to operate the doorbell.

You can test to see if the problem is in the bell by shorting the wires (obviously, you will need the power on to do this). If the bell doesn't sound, the problem is probably in or near the transformer.

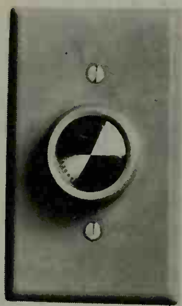
The transformer reduces the voltage from the regular house current to between 15 and 24 volts. If the transformer is working properly, the problem usually can be found in the wiring between the transformer and the bell. The wire may be broken or there may be a short circuit caused by faulty insulation. To find the problem area, first check all the places where the wire is exposed. If your visual inspection fails to locate the trouble spot, try using a test meter. As a last resort, the wire may have to be replaced.

THREE-WAY SWITCHES

Three-way switches allow you to control a light from either of two switches or from a lamp and a wall switch. This control can be



Three-way switch wiring


A dimmer switch


Joining the wires from the dimmer switch and the wires from the wall switch

very convenient in certain situations. For example, an outside light can be controlled from the wall of the house and from the garage. Another useful place for a three-way switch is at the top and the bottom of a flight of stairs.

The three-way switch gets its name from the three wires in each switch. A regular light fixture, controlled from only one location, has only two wires. If you are planning to install a three-way switch, you may need the help of an experienced electrician because the necessary rewiring can be complicated. In addition, you may need to drill through walls and floors.

Basically, one wire is used to connect the two switches, one wire from each switch is connected to the light fixture, and one wire from each switch is connected to the electric circuit. This sounds fairly simple, but in practice, it involves a lot of wiring.

DIMMER SWITCHES

Dimmer switches allow you to control the amount of light a fixture produces. Some dimmer switches are dials that give you a full range of light from only the barest glimmer to full brightness. Others have high, low, and medium settings. Dimmer switches are fairly easy to install.

Before you start working, shut off the circuit that carries current to the switch. Remove the two screws that hold the switch faceplate in place. If the faceplate has been painted, it may adhere to the wall. In removing it, be careful not to chip the paint on the faceplate or on the wall around it.

When the switch is exposed, unscrew and remove the two mounting screws that hold it in place. Pull the switch and the attached wires out of the box. Loosen the two terminal screws that attach the wires to the switch, then remove the switch.

Dimmer switches come with two wires attached. Each of these wires is to be color-matched and joined with one of the wires from the outlet. The two joined insulated wires (one from the dimmer switch and one from the outlet) should be twisted together, and the exposed portions should be covered with a solderless connector. Do the same with the other pair of wires from the dimmer switch and from the outlet.

The wires should be fitted back in the outlet box. The dimmer switch is placed over the wires and secured in position with screws. Finally, replace the faceplate.

9
Planning Wiring

To meet all your needs for electric power, install enough lighting and general-purpose outlets and circuits. There should be sufficient special-purpose circuits to handle larger appliances that are generally operated in one location. A rule of thumb is to have lighting branch circuits with a total capacity of 3 watts per square foot of building area. There should be one 15- or 20-ampere branch circuit for each eight to ten convenience outlets or duplex receptacles in the house.

The National Electric Code, a recognized authority, has established guidelines on specifications and safe practices for electrical systems. The code requirements in your own locality may differ in some details. These are minimum requirements for safety and do not necessarily cover adequacy of the wiring for convenience.

Now let's check the wiring system for adequacy. Convenience outlets or duplex receptacles should be spaced at most 12 feet apart, so that no point on the wall measured along the floor line will be more than 6 feet from an outlet. Any wall space more than two feet wide also needs an outlet.

Outlets in the kitchen, laundry, pantry, dining room, and breakfast room should be equally divided between two or more 20-amp branch circuits.

Some homeowners have each kitchen outlet installed on an individual circuit. This increases the cost of installation, but the extra load-handling capability is worth the difference.

Under provisions of the National Electric Code, all outlets are to be grounded. Grounded outlets permit the connection of two-wire cords and parallel-blade plugs used on appliances, as well as three-wire plugs or cords that are attached to devices that must be grounded.

Weatherproof outlets are desirable on the driveway side of the house and on the opposite side, about 4 feet above the ground. Additional weatherproof outlets may be needed in outside walls of the house or on patios or porches to serve the many appliances used in outdoor living.

All circuits serving outside outlets must be protected by ground-fault interrupter equipment that automatically disconnects the circuit in case something goes wrong with the wiring or the appliance that would cause an accidental shock.

Install convenience outlets in the wall 18 inches above the floor and no more than 12 feet apart in bedrooms, living room, and dining room. Additional outlets take care of furniture arrangements.

Install one wall outlet in the dining room above table height to connect portable cooking or warming appliances from the table. Put kitchen and work area receptacle outlets 8 inches above the worktable level.

Clock outlets in kitchen and workshop areas should be connected to lighting circuits not controlled by the wall switch.

Center the outlets for ceiling lights in bedrooms, dens, kitchens, dining and living rooms, halls, passageways, and stairways. Lights in bathrooms are placed above mirrored cabinets and overhead in shower stalls.

Work areas in kitchens, laundries, and home workshops need lighting outlets directly over task areas. Overhead lighting is also recommended in basements and recreation rooms.

Outlets for lights are desirable over or alongside each outside entryway to the house and for flood lights around the dwelling. Outlets for the switch control of these lights are placed in the wall about 48 inches above the floor at the latch side of entrances.

You can install dimmers in place of off-on switches to control the amount of light for different moods or effects.

Three-way and four-way switches are needed to control lights from two or more locations. These may be at entry points to the living room, dining room, kitchen, stairways, basement, and recreation room. A switch control for outside floodlighting outlets may be desired in the master bedroom.

Time clock switches for inside and outside lights will turn lights on and off at preset times. This will allow you to return home to a lighted house. It will also discourage burglars while you are away. Photoelectric cells may be used to turn lights on at dusk and off at dawn.

Lighting outlets may also be controlled by low-voltage switching systems that are currently available. In these, the actual switching is done by a relay operated by a 24-volt circuit and controlled by low-voltage switches. Any number of switches to control the same light outlet can be easily and inexpensively added to the circuit. In addition, the use of master switches allows control of many lighting outlets from several different locations.

At least one receptacle outlet for floor or table lamps in the living room should be controlled by a switch, especially when ceiling outlets are not used. Here, as well as in the bedrooms, silent, or mercury, switches may be desirable. Most low-voltage switching systems are silent.

A bathroom may require an outlet for a heater. The frame of an electric heater must be grounded for safety. Receptacles for electric shavers, toothbrushes, makeup lights, and other fixtures may be incorporated in the lighting fixture over the mirror.

Lighting fixtures in this bathroom are placed above the mirrors.

In the kitchen and the workshop, individual circuits for each receptacle provide minimum interruption in the use of appliances. These circuits should accommodate 20 amps at 120 volts as a minimum requirement. They include outlets for irons, automatic washers, garbage disposals, dishwasher, roaster, refrigerator, food freezer, and the like.

Individual power circuits of 240 volts are needed for such major appliances as electric ranges, tabletop cooking units, wall ovens, clothes dryers, space heaters, and powerful air conditioning equipment.

Thought should be given to the proper selection of wire sizes for circuits throughout the home. General-purpose circuits and lighting circuits should be No. 12 copper wire or larger. In some old installations, No. 14 wire was used for these circuits. The wire sizes are increased whenever heavier loads or larger appliances or equipment are expected. Plan for maximum rather than minimum capacity.

Protective devices built into home electric systems for safety and convenience are of two approved types, circuit breakers and fuses. Both give acceptable protection for the wiring system.

Use only fuses or circuit breakers of the proper size to protect the wire in the circuits—generally, a 15-amp fuse or circuit breaker with No. 14 wire and a 20-amp fuse or circuit breaker with No. 12 wire.

The procedure used to restore interrupted service varies. A blown fuse must be replaced

The hanging fixture in this dining room is centered over the table and is controlled by a dimmer switch.

with a new one of the same capacity. Resetting a circuit breaker requires operation of a toggle, or switchlike handle, to restore the circuit connection. Replacing a fuse or resetting the circuit breaker should be done only after the cause of service interruption has been eliminated.

Circuit breakers or fuses may be installed in a cabinet whose exterior trim and covers are flush with the walls in which they are placed. The interior of this cabinet should be covered with a plate so that only the tops of the fuses or the circuit breaker handles are exposed and all wiring connections are concealed.

The main service entrance of wires and load center in most homes is near the point of entry of the power lines. Never locate these in a cabinet or closet where they are not readily visible or accessible.

Most homes today require a capacity of between 100 and 200 amperes.

When much of the heavy electrical load is some distance from the main service center, a subcenter is extended with a second distribution panel to shorten the length of the circuit conductors.

In the choice and planning of load center equipment, branch circuits of 120 and 240 volts must be provided to care for the needs of installed circuits. At least two 120-volt and one 240-volt circuit spaces should be allowed for future circuits.

The cabinet door of each load center has a table of numbered circuits. You should list on this table exactly which area or individual appliance is served by each circuit.

Finally, have your work checked and inspected for safety.

10
Good Lighting

Good lighting adds to the beauty, cheer, comfort, convenience, safety, and value of your home. It helps you move about and work rapidly and safely and do tasks when and where you wish. It protects eyes from strain. And it helps you relax or concentrate. To obtain these benefits, you need good task (or local) lighting and general background lighting—each helping the other—to attain proper levels and balance for usual activities.

For most tasks, soft, diffused light from a fairly large or long source helps avoid spotty reflections and harsh shadows, but fine hand sewing or detailed hobby work may require some strong, direct, additional light to bring out details. Choose and place local task lighting equipment in relation to eye levels—seated or standing. Average eye heights are 40 to 42 inches for persons seated in lounge chairs and 61 to 64 inches for persons standing.

Workplaces must be well lighted, but when the general lighting is good, local light is needed only on the task you are doing.

The place where you do the work is important, too. For example, you can make good use of a task light (because of reflection) by placing a desk, sewing center, or workbench against a wall or in a corner. Areas near the task should not be brighter than the task area and should not have less than a third of its illumination if the task is to consume much time. If desk tops are dark, light-colored blotters, which reflect light, help achieve this relationship.

When you choose lights, consider color effects as well as the amount of light. Many bulb and tube finishes enhance cool or warm colors, but some affect the output of light considerably. Choose white or warm white tubes and inside-frosted and white bulbs for the most efficient light. Choose deluxe warm or cool white tubes or tinted bulbs to bring out colors of furnishings.

Avoid daylight tubes or bulbs that produce light unflattering to skin, food, and furnishings. Color is an important aid to light. For ceilings, choose white (for work areas), near-white, or pale tints. Elsewhere, light to medium colors reflect light fairly well and make rooms seem larger. Dark colors absorb and waste light, as dust and dirt do. Dark-light contrasts, shiny finishes, and glare are annoying and can make even simple tasks more difficult.

Portable lamps or special-purpose fixtures that direct light over task areas provide light for close work. Well-designed types contribute to balanced

The overhead globes and recessed fixtures provide good, balanced light in this kitchen.

Recessed fixtures produce soft, diffused light accentuated by the lamp and spots.

This portable lamp adds strong, direct light for desk work.

lighting around tasks and add to the overall effectiveness of room lighting.

For long-range value, economy, and comfort, give consideration to the types and locations of fixtures and portable equipment. They should be fairly near the ceilings, walls, objects, or people that you are trying to light. Well-planned, balanced lighting in each room creates a harmonious decorative effect throughout the house.

Off-center and suspended equipment bring light close to the task and add decorative interest but may limit the rearrangement of furnishings. Recommended hanging heights range from 30 to 36 inches over a dining table to 48 inches above laundry centers or workshop benches.

Just as daylight needs some window treatment for full effectiveness, artificial light needs improvement. Some devices to improve

Suspended lamps should be approximately three feet above a kitchen table.

the quality of artificial light are bulb finishes, bowls, globes, shades, shields, louvers, and reflectors. They enlarge the source, conceal it, soften or diffuse the light, reflect and direct it, and increase illumination where needed.

Dimmers and step switches let you dim or brighten light. Adjustable positioning devices also are useful. These include reels or pulleys with counterweights to raise or lower fixtures and wall lamps, adjustable height shafts in floor and table lamp bases, and various swing-arm and swivel devices or flexible shafts that bring light closer to work or help you to position it or decrease reflected glare or shadows on your work.

Good lighting fixtures to suit all styles of furniture are available. Large or long ones are good buys that should maintain their value, particularly if they follow room proportions. Large or long fixtures couple low brightness with a wide light spread.

Recessed fixtures require thoughtful handling. Near-white ceilings, lighted from below, and fairly light floors can dispel gloom. One recessed fixture should be used for each 40 to 50 square feet.

Especially good are inconspicuous fluorescent fixtures. For local light, low brackets and built-in soffits—over sinks, buffets, sofas, and desks—bring the light close to the subject. For general lighting, ceiling fixtures and fixtures behind window valances and ceiling cornices and in coves produce balanced overall lighting, which can easily be supplemented by local lighting.

Small to medium rooms require 3 to 8 feet of shielded tubes when they are used with a ceiling fixture, or 6 to 16 feet without one. Large rooms with no ceiling fixture should average about 1 foot of tube for each 15 square feet of floor space—roughly 16 to 20 feet of tube for large living rooms. Use tubes 1.5 inch in diameter (T-12 tubes) unless space demands tubes 1 inch (T-8) in diameter.

Large panel fixtures and tubes installed between ceiling beams are practical in work areas and elsewhere if they have dimmers. Plastic diffusers suspended on hangers below the tubes, make a smooth and easily maintained installation. In building or remodeling, balance

This fixture can be raised or lowered to meet lighting requirements.

Hanging fixtures are available in a wide variety of styles to match any room decor.

Well-planned recessed and spot lighting in this foyer produces a dramatic effect.

high initial costs against costs of ceiling finishing, fixtures, and future maintenance.

The main problem with fluorescent lighting is choosing fixtures of the right size and quality; you cannot change the light output later, as you can with incandescent lighting. Ask about radio interference suppressors, sound rating, starting speed, and dimming possibilities before you buy fluorescent fixtures.

LAMPS

Well-styled lamps, all appropriately spaced, can add to the attractiveness of a room while meeting the requirements of task lighting. Several points to look for in good lamps are bulbs located low in the shade; undershade devices to reflect, refract, or diffuse the light; broad, white-lined shades open at the top; and proportions that are neither squat nor gigantic.

Thin, long, portable lamps fit into tight places, under cabinets, and in, on, or behind furniture or room dividers. Use one lamp for each 40 to 50 square feet of floor space.

Select a lampshade that blends with the background and transmits some light through the sides. Usually light-colored translucent shades are preferable because opaque shades create spots of uncomfortably high brightness above and below the rim of shade. Shades that are too thin show distracting "hot spots." Avoid narrow, deep shades or shades that are too shallow. Be sure the lining is white.

Most lamps are chosen for decorative suitability and for the amount and quality of light produced. Occasionally you may need a lamp that is primarily functional. Several types of functional lamps are specifically designed for study desks, for example.


The lamp on the table helps balance the room lighting and the room furniture.

Standards have been established for study lamps to meet the Illuminating Engineering Society requirements for comfortable vision. These include an adequate amount of light (70 footcandles) with light distributed upward, and low contrasts in amounts of light around the task. The lamp should be capable of casting diffused light. The amount of light shining through the shade should be limited (50 to 150 footlamberts, the measurement of diffused light) for eye comfort. Study lamps that meet these standards are tagged "Better Light, Better Sight."

You may decide to do it yourself and make your lamp or fixture from scratch. You can buy parts in some hardware, variety, hobby, and lighting equipment stores. Lamp-making kits are also available. You will be limited only by your imagination. You can make attractive, unique equipment inexpensively. If the end product is to be functional, consider many of the points that have been discussed previously.

Light in the right place is critical if it is to be used for difficult, prolonged tasks. Lighting authorities have worked out measurements for placement of light sources in relation to tasks. One rule of thumb for placing a lamp is that the bright inner surface of the shade should never be visible to the user. Tall table lamps and floor lamps should be placed at the right or left rear corner and close to the chair in which the user will be working.

BULBS

Common incandescent bulbs are inexpensive, relatively hot, small sources of bright light. Their average life is 750 to 1000 hours. Bulb ratings of 1200 to 2500 hours sacrifice some light output for longer life.

Bulb failures occur early when house voltage exceeds the voltage rating marked on the bulb (usually 115 to 130 volts), or the bulb overheats in a small or poorly ventilated fixture, or it receives rough service or unusual vibration.

At extra cost, you can buy three-way or high-low bulbs to change light levels, and large bulbs with special finishes to provide better diffusion of light.

Comparatively, fluorescent sources—tubes, circles, or square panels—give greater diffusion at lower brightness. They emit three to four times more light and last six to ten times longer than incandescent bulbs. They also feel cooler. Their average life of 7500 hours balances against a higher initial cost. Frequent starting shortens the life of fluorescent tubes, however.

The bulb used in a lamp or fixture is critical to producing enough light of the right kind. Fluorescent tubes of the wrong color can "kill" the colors in an attractive room. An incandescent bulb that is too small does not provide the amount of light needed, and a bulb too large for a fixture causes "hot spots" and can melt plastic. Colored and decorative bulbs need to be used with caution. Inside-frosted or white bulbs are preferable for most lamps and fixtures.

A word must be said about fluorescent tube colors. Deluxe warm white (WWX) and deluxe cool white (CWX) are most frequently used in homes. Warm white enhances warm colors and flatters complexions, but cool white is preferable if blues and/or greens are predominant in the color scheme.

For incandescent bulbs, the size you choose is determined by the equipment in which it is to be used.

The wise consumer today takes advantage of information included on the "sleeves" or jackets in which bulbs are packed. Labels list initial lumens and bulb life as well as wattage. *Lumen* may be a new word to you; it is a measure of the initial light output of a bulb. Fluorescent tubes are more efficient than incandescent bulbs. A 40-watt fluorescent tube produces 2080 lumens, but a 40-watt incandescent bulb produces 450 lumens. Quite a difference! Some incandescent bulbs of the same wattage also are more efficient than others. Read the information on the package before you buy.

Lumens increase as wattage increases. A 100-watt bulb produces 1700 lumens, while a 200-watt bulb produces 3900 lumens.

Consumers investing in long-life bulbs may not realize they are sacrificing light for long life. You get longer life but lose light and pay the same for electricity. Restrict your use of these bulbs to hard-to-reach fixtures in stairwells, attics, or high ceilings. Where long-life bulbs are the primary source of light, use a higher wattage bulb (provided the equipment can accommodate the size and heat) to compensate for the reduced output.

Information on the bulb sleeve includes the average expected life of the bulb. New bulbs on the market are reported to last longer than standard bulbs, with less loss in light output. One, a bulb filled with krypton gas, is called a "super bulb;" another bulb utilizing a "power-coil" filament is called "Soft-White Plus." Both cost more than standard bulbs.

Check lumen rating as well as bulb life before making a choice.

Selecting bulbs and lighting equipment may require more know-how and time than you anticipated. But the results—more attractive rooms with comfortable, adequate, visual conditions—make it worth the effort.

FIXTURES

When you buy a new house or redecorate an older one, you can often reduce the expense of adequate lighting equipment with a little ingenuity in modernizing or making equipment.

To obtain portable equipment inexpensively, consider buying kits for study, wall, and vanity lamps or for improving poor lamps. Lamp improvers also include 5-inch-diameter (R-40) white indirect bulbs; wide harps, threaded holders, and bowls or disk diffusers; shade risers; and miscellaneous oil-lamp converters.

Spray paint in color or metallic finishes gives old equipment a new look or new efficiency. When you spray paper or metal lampshade liners white, you greatly increase the light output of a fixture.

Fixture improvers include special fixture bulbs, candle shades, screw-in adapters, plastic converters, diffusing lanterns, and other shielding material.

Ceiling fixtures centered in the room have become so unpopular that they have disappeared from many rooms. General lighting from other sources must be provided to compensate for this loss of light.

Fixtures now are often installed near the edges of the room to provide both general and task lighting. Chandeliers used in living areas are placed over baby grand pianos, sofas, or other appropriate large pieces of furniture. Single or clustered pendant fixtures, placed off center, may be used for task or accent lighting.

Recessed fixtures can create dramatic effects, but you need more fixtures and higher total wattage than with other fixtures. If much of the light for the room comes from recessed fixtures, you need almost twice the total wattage required with ordinary fixtures. When designed and installed properly, recessed fixtures can bring attractive and effective lighting to a room.

Structural lighting, too, is effective if properly designed and installed, but is often disappointing when done without flair.

Select a fixture that suits the decorative scheme, provides enough light without distracting glare or brightness, accommodates bulbs or tubes of the required wattage, and distributes the light as needed. No part of the fixture should be so bright that you are uncomfortable when you view it directly. There should be no great contrast between the brightness of the fixture and the background.

For help on how to improve, make, or choose equipment and where to put it, consult your power company, home extension agents, homemaking and shop teachers, and lighting dealers and distributors.

11
Outdoor Lighting

In times past, outdoor lights were incandescent bulbs with a porcelain reflector used sparsely on poles or buildings on urban and rural property. Today there are many types of outdoor bulbs and their use has risen greatly. Contemporary trends give more emphasis to beautification, security, safety, and convenience in outdoor lighting. Work or leisure activities during night hours have vastly increased.

We are somewhat accustomed to the glare and poor distribution of lighting outdoors. In urban and suburban areas, bulbs with little or poor shielding glare at us from parking lots and roadways. In rural areas unshielded bulbs can be seen for miles like tiny beacons, but as you approach the source, the glare becomes very apparent and annoying.

Shielded fixtures that reduce glare and control light are more expensive and less efficient. However, better fixtures enhance the surroundings and provide the needed light without annoyance. Many existing outdoor lighting fixtures can be shielded to reduce glare or stop light from shining where it is not wanted.

Local or spot lighting outdoors is usually based on esthetics or ability to see rather than calculations of illumination levels. With a portable incandescent bulb holder and an extension cord, you can try various sizes of incandescent bulbs in different locations. This approach will give you an idea of how the permanently installed lighting will appear. For lighting larger areas, you can get help from electric company representatives, electrical contractors, and manufacturers of bulbs and fixtures.

Electric wiring for outside lighting must be weatherproof, in accordance with the National Electric Code and local regulatory agencies.

Incandescent bulbs or fixtures for outdoor use are simple and inexpensive. The "gooseneck" fixture, a porcelain reflector fastened to a pipe curved like a goose neck, is still in use, mounted on the sides of buildings or poles. New installations use a floodlight holder for incandescent lamps with built-in reflectors (PAR). Some fixtures completely shield the bulb, permitting use of indoor bulbs. Others shield only the bulb base, and outdoor or weatherproof bulbs must be used. Incandescent bulbs are particularly useful when they are to be turned on and off frequently.

Outdoor incandescent bulbs are available in colors for decorative emphasis, for limiting insect attraction, or for effects on vegetation. Yellow incandescent bulbs provide three fourths of the light output of white bulbs, but they hold insect attraction to a minimum. Blue, green, yellow, amber, pink, and red bulbs can be used separately or in combination for decorative effects. Reflector bulbs (PAR 38) in colors are normally available at ratings of 150, 100, and 75 watts.

Regular pear-shaped bulbs in colors are available at standard ratings—40, 60, 75, 100, and 150 watts.

Tungsten-halogen bulbs are incandescent bulbs with longer service life. They are used in higher wattage floodlights. Tungsten-halogen bulbs are normally tubular, with electric contacts at each end, but some are reflector bulbs with regular screw bases.

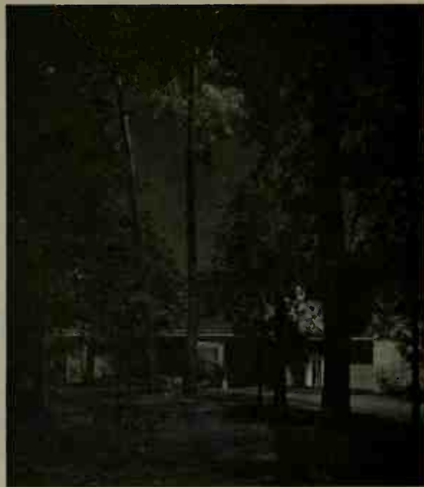
Fluorescent tubes can be used for outdoor lighting provided that a weatherproof fixture is used, the tubes are enclosed in a transparent cover that can withstand temperatures below 50° F, and special ballasts or fixtures are used for tubes that must operate at temperatures below freezing.

A fluorescent tube's light output efficiency at indoor temperatures is normally two or three times that of an incandescent bulb. In outdoor temperatures at or below freezing, without enclosed fixtures, it is only slightly more efficient than an incandescent bulb.

Most outdoor fluorescent fixtures are either 4 or 8 feet in length, and they hold two or more 4-foot or 8-foot tubes.

Gold or yellow fluorescents are used to reduce insect attraction, yet they provide about three fourths of the output of white tubes having the same wattage ratings.

High intensity discharge bulbs (HID) are used for floodlighting large areas such as roadways, parking lots, and yards. All three types of HID bulbs—mercury, metal halide, or high-pressure sodium—require an electrical ballast which is different for each type and size (wattage) of bulb. The fixture (luminaire) shell, or housing, may be the same for equivalent wattages of the three types, but the internal electrical components differ.



Clear mercury bulbs give a moonlight effect. The owner wanted lighting to discourage prowlers.

High-pressure sodium bulbs produce an intense yellow light. Metal halide bulbs produce a white or slightly greenish light. Mercury lamps produce bluish white or greenish white light. Mercury bulbs are available in sizes from 50 to 1500 watts. Metal halide sizes are 400 to 1000 watts; high-pressure sodium 250, 400, and 1000 watts.

The lumen output is about equal for one 250-watt high-pressure sodium, one 400-watt metal halide, three 250-watt mercury, three 500-watt incandescent, and ten 40-watt fluorescents. Metal halide or combinations of metal halide and high-pressure sodium are used for architectural floodlighting.

Because HID bulbs require about five minutes to start, they are not suitable in situations where they will often be switched on and off.

Mercury luminaires, usually 175 watts known as "dusk to dawn," have been widely used for rural yard or security lights. Operated by a photoelectric control, the luminaire unit is similar to a street light in that it operates automatically, turning on at dusk and off at dawn.

Two 150-watt recessed fixtures with diffusers light the entry and steps, while two 75-watt recessed units highlight the shrubs.

Lighting at the foot of the wall, around the edges of the patio, and in the trees produces this dramatic effect.

Blue-white incandescent downlights accent the texture of the brick and highlight the sculpture. Standard incandescent downlights accentuate the plantings in front of the playroom.

Mercury bulbs rated at 50 and 75 watts are used in post lanterns in yards or at driveways and are operated either by switch, time clock, or photoelectric control.

Low-voltage outdoor lighting consists of 6- or 12-volt bulbs operated from an isolation transformer that converts 120-volt current to 12 volts. The bulbs are usually 25- and 50-watt incandescents. The total number of bulbs that can be operated on one transformer depends on the capacity of the transformer—normally about six 50-watt bulbs. Such lighting is usually used for decoration or display.

Additional equipment for automatic lighting that turns on at dusk and off at dawn is relatively expensive.

Night-flying insects (except mosquitoes) are attracted to blue or ultraviolet light. Insect traps use ultraviolet bulbs, sometimes in combination with chemicals, to trap insects.

Of the HID bulbs, high-pressure sodium attracts fewest insects. Metal halide bulbs attract more, and mercury bulbs the most. Outdoor bulbs should be placed so that the insects that collect around them will not fall on walks or around doorways.

SWIMMING POOLS

Swimming pools can be lighted by overhead or underwater lights (sometimes in combination). Underwater lights installed in the side of the pool below water level require safety inspections at least once a year. Underwater fixtures deteriorate rapidly and require frequent renewal of gaskets and other parts or replacement of the entire fixture.

Satisfactory lighting for pools can be obtained from floodlights on 20-foot poles located 20 feet from the pool edge. Electric wiring to fixtures must include a separate grounding conductor and be more than 10 feet from the edge of the pool. Ground-fault interrupters (GFI) are usually required by regulatory codes for any wiring around pools.

An illumination level of 10 footcandles (lumens per square foot) is recommended at the pool surface. Using underwater light, sixty lumens per square foot will be required to produce about 10 footcandles at the pool surface. For floodlights, 35 to 50 lumens per square foot will be required to provide 10 footcandles at the pool surface. It is critical for safety to see clearly at night to the bottom.

Index